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ABSTRACT

This teacher's guide presents 12 hands-on laboratory activities for high school science classes that cover the environmental issue of water resources in California. The activities are separated into three sections. Five activities in the section on water quality address the topics of groundwater, water hardness, bottled water, water purity, and water purification. Four activities in the section on water and the environment address the topics of water clarity; rainfall, geography, and vegetation patterns in California; toxins in water; and water ecosystems. Three activities in the section on water and people address the topics of water distribution, water conservation, and water treatment. The guide contains a glossary of 34 terms. The attached "Layperson's Guide to Drinking Water" explains some of the major concerns and controversial issues about today's drinking water and the kind of decisions that need to be made. It also contains a sliding chart of water facts, and a California Water Map. (MDH)

ED 361 170

PROJECT WATER SCIENCE

General Science
High School Level

Prepared by the
Water Education Foundation

Project Water Science

Secondary Environmental Science

Teacher's Introduction

Project Water Science is intended for use in earth and physical science classes. It gives secondary science teachers a series of hands-on exercises organized to cover one of the most important issues of our times—water, and its importance to our environment and our lives.

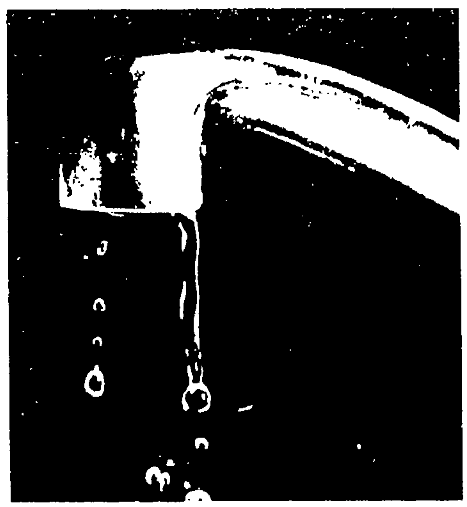
Consistent with the new *Science Framework*, this material is organized thematically and cuts across all areas of science. These labs can be used as a unit or integrated into an existing water unit. All student pages may be photocopied.

Teacher's information for each of the three sections appears on the blue pages.

Project Water Science is divided into three sections
Water Quality,
Water and the Environment, and
Water and People.

Materials accompanying _Project Water Science_
California Water Map
Layperson's Guide to Drinking Water
Water Trivia Facts Card
Water Education Foundation brochure and order form
Evaluation form

Optional
Video—*Waterquest*



Teacher and Student guides are published by the Water Education Foundation. The guides were jointly funded by the Foundation, the California Department of Water Resources and the California Department of Education, Environmental/ Energy Education Grant Program. Additional educational materials are available from the Water Education Foundation, 717 K Street, Suite 517, Sacramento, CA 94814, 916-444-6240

A Look Inside

Water Quality

page

Water and the Environment

Water and People

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The mission of the Water Education Foundation, an unbiased, nonprofit organization, is to develop and implement education programs leading to a broader understanding of water issues and to resolution of water problems.

SECTION 1 Water Quality

Teacher's Information Labs 1-5

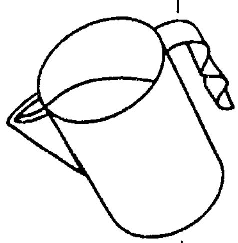
LAB 1
HOW LOW CAN YOU GO?
Groundwater and Porosity

Objective

Students will become aware of some of the pressing issues involving contamination of our limited surface and groundwater supplies.

Demonstration materials needed

1. large glass bowl, jar or fish tank
2. glass beads, fish tank rocks or sand
3. food coloring



Lab Hints

Use pea-size gravel, fine sand, and soil typical in your area.

Activity

1. Introduce this learning unit with the Reading and by referring to recent news articles regarding water quality problems. Ask the students if they are aware of any pressing local water quality issues.

2. Hand out photocopies of the *Layperson's Guide to Drinking Water* p. 2. Promote discussion about the issues.

3. Using a glass bowl, a large jar or fish tank, simulate a ground water basin by adding sand, or gravel and fish tank rocks or another medium like glass beads. By adding a measured amount of water, students can observe recharge. withdrawal and water filling the crevices. Using a straw to simulate a well, siphon out water (or use aspirator) and note the water level on the side of glass bowl, jar or fish tank with a grease pencil. A cone of depression should be formed if particles are small enough and extraction is large enough.

Extension Activity

Suggest that some of the groups change the proportion of sand to gravel to soil. Discuss how the pore size may change with the mixture. Ask what would happen if the gravel was angular as opposed to round.

LAB 2
TO SUDS OR NOT TO SUDS
Water Hardness

Objective

Students will evaluate the hardness of tap water and recognize hardness as an important factor in water quality.

Lab Hints

Small jars like baby food bottles may be used if test tubes are not available. Use liquid soap, not detergent. For the mystery sample, add a handful of Epsom salts to a liter of tap water. Epsom salts contain magnesium, and will make the sample a good example of hard water.

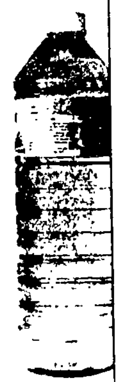
Extension Activities

See if students can design another lab to test hardness. This could be washing an oily rag in different types of water. Also suggest one group use detergent for the initial experiment. Discuss how water softeners work. Show the build up of scale in a tea kettle or hot water pipe. Invite a local plumber in to talk about scale and water softeners.

LAB 3
HOW DOES IT TASTE?
Is Bottled Better?

Objective

Students will recognize taste as a criterion of water quality



Reading

Have students read pp. 12—13 in *Layperson's Guide to Drinking Water.* These pages may be photocopied.

Lab Hints

Collect water from various sources (tap, distilled, bottled spring, carbonated, etc.) and put into plain bottles labeled with a number. Have unsalted soda crackers available to eat between samples to remove tastes from mouth.

Extension Activity

Have students test water samples for hardness. Relate mineral content to taste.

LAB 4
PURE AS THE DRIVEN SNOW?
Water Quality in Drinking Water

Objective

Student will measure two indicators of water quality, pH and chlorine level, and be able to identify their importance in evaluating drinking water.

Reading

Have students read pp. 8-11 in *Layperson's Guide to Drinking Water*. These pages may be photocopied.

Lab Hints

Part A: Remind students that food coloring is already diluted at 1 part coloring to 10 parts water. Put white paper under clear containers so students can observe the color changes. If you don't have enough clear containers, white plastic egg cartons may be used.

Part B: Use the same water samples as in Lab #3, *How Does It Taste?* This will give the students opportunity to discuss the relationship of water quality to taste. Use any pool or spa test kit that contains OTO, orthotolidine, for testing chlorine, and phenol red for testing pH. You may want to review the concepts of pH, acidity, and alkalinity with the class. If you have limited pool test kits, you can have half the class work on part A, while the other half works on part B. Other methods of testing pH, like litmus paper, may be substituted.

Extension Activity

Have students allow water samples in part A to evaporate to see if food coloring residue reappears. Have a local water district official come talk to the class about local water treatment processes. Ask about the local THM levels. Possible research project: What are the newest advancements in water treatment?

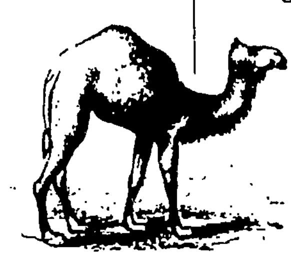
LAB 5
"WATER, WATER EVERYWHERE, BUT NOT A DROP TO DRINK..." How to Build a Solar Water Purifier

Objective

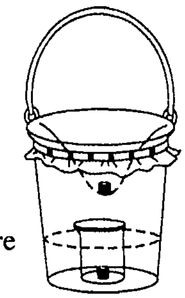
Students will build a water purifier using the principles of the hydrologic cycle. Students will recognize the finite nature of water as a resource.

Pre-Lab activity

Review the hydrologic cycle with the students. Boil water, condense steam on a cold plastic cup. Using a lamp, melt an ice cube, and then allow the water to evaporate.



Lab Hints



Students can bring in their own buckets or coffee cans and build individual stills or work in groups.
Use plastic or glass containers if beakers are unavailable. Use light colored or clear weight on the plastic wrap.
(Dark weight will absorb heat and can burn through wrap.)

Extension Activities

Have some of the group put other materials beside salt in their water (e.g. food coloring, lemon juice, sugar, etc.)

Use Trivia Game to discuss the amount of fresh and salt water in the world.

Assign a research project on the Yuma, Arizona desalination plant or the Santa Barbara desalination plant.

Contact a branch of the U.S. Navy and ask how large ships, such as aircraft carriers provide enough fresh water for their crews.

Discuss other saline water problems: salt water intrusion in coastal areas, agricultural drainage problems like those at Kesterson Reservoir, Colorado River water and agricultural drainage.

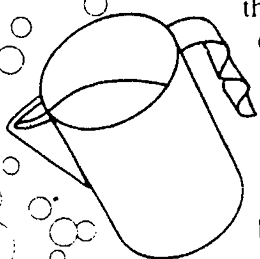
LAB 1

How Low Can You Go?

Groundwater and Porosity

Introduction

Water falling on the ground either runs off the surface, or soaks into the ground. The amount of water that can be absorbed into the ground, and how far down it travels, is dependent on the size and shape of the particles. The water molecules move into the spaces, or pores, between the particles.



Question

Which kind of medium can hold the most water?

Materials

- sand
- gravel
- garden soil
- 4 glass or clear plastic containers/group
- graduated cylinder
- water

Procedure

1. Fill the containers with sand, gravel, garden soil, and an equal mixture of these three substances. Shake the containers to distribute the contents. Label each one.
2. Add water from a graduated cylinder to each container. Pour slowly. Measure how much water each container will hold before overflowing.
3. Record your results in the table.

Hypothesis

____

____

Results

1. Which medium absorbed the most water?

____

____

____

____

Data

sand	ml
gravel	ml
soild	ml
mixture	ml

2. Which medium absorbed the least water?

____

____

3. What does this mean about the pore space in each container?

____

____

____

____

____

4. In a rainstorm, which medium would have the heaviest runoff?

____

____

Conclusion

____

____

To Suds or Not To Suds

Water Hardness

LAB 2

Introduction

One of the characteristics of water quality is its hardness, which refers to the amount of minerals dissolved in it. These minerals include calcium and magnesium. Hard water has many dissolved minerals, which interfere with its usefulness in washing. The minerals react with soap to form scum instead of suds. These minerals can also form a deposit called scale inside boilers and hot-water pipes.

Question

How hard is our tap water?

Materials

test tubes
soap solution (not detergent)
glass markers or crayons
water solutions: distilled, tap, bottled spring, salt
mystery water sample

Procedure

1. Pour 5 ml. of distilled water into a test tube. Add 1 drop of liquid soap solution, cover tube with thumb, and shake. Continue adding drops of soap solution until you have lasting suds. Shake vigorously after each drop. Use this as a control.

2. Repeat procedure with other water samples. Use a clean, labelled test tube for each sample. Record the number of drops of soap solution necessary to produce lasting suds.

Hypothesis

____

____

Results

1. Is your tap water hard or soft?

____

____

2. Which was the hardest water?

____

Which was the softest?

____

3. Was there any cloudiness in any of the water samples after adding soap? ____________ What do you think this is?

____

____

____

4. Which would be better for washing clothes, distilled water or salt water? ____________ Why?

____

____

____

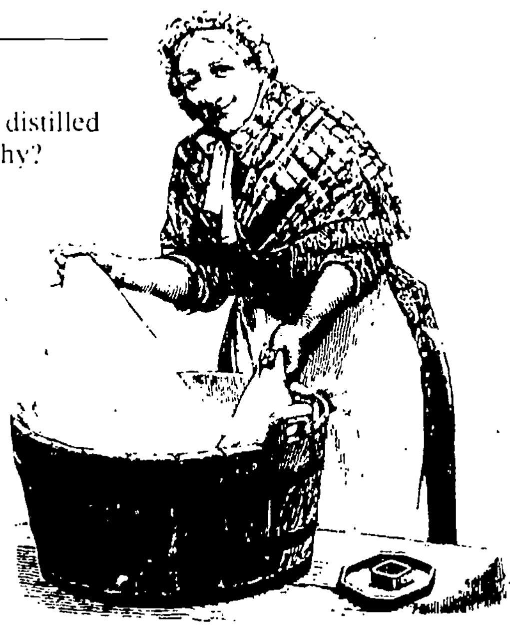
Data

distilled water	drops
tap water	drops
bottled spring water	drops
salt water	drops
mystery water sample	drops

Conclusion

____

____



LAB 3

How Does It Taste?

Is Bottled Better?

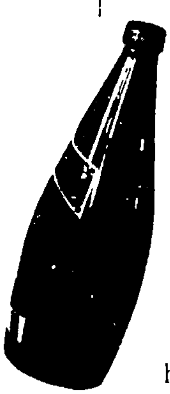
Introduction

The bottled water industry is booming, but is bottled water really "better" than tap water?

According to the industry, more than $2 billion in bottled water was sold in the United States in 1989, double that of five years before. California leads all other states in bottled water consumption and accounts for almost half of the bottled water consumed in the nation. One out of three California homes uses bottled water—double the national average.

Do Californians drink bottled water for safety or taste? The reasons behind this boom are hard to pin down or quantify. Some consumers buy bottled water because they believe its taste is superior to tap water's.

The expensive, imported brands, too, have a definite "snob appeal"—particularly when served up with a twist of lime. In this, the era of physical fitness and well-being, there is also an allure to the "naturalness" touted by some brands. The safety of tap water is a concern, as more refined analytical techniques make it possible to detect smaller and smaller amounts of various contaminants with little conclusive evidence of their long-term health effects.



But just as tap waters vary from region to region, so do bottled waters vary, both in type and quality. In California, water sold as "mineral water" must contain more than 500 milligrams per liter of dissolved minerals—far more than most tap waters.

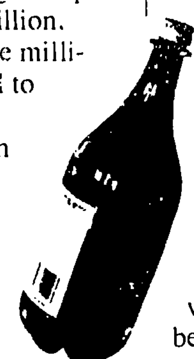
Of course, any water except **distilled** is technically a "mineral" water. Since water is a solvent, it naturally picks up an assortment of minerals and other substances on its trip through the hydrologic cycle. (The substances found in water are measured in milligrams per liter or in parts per million, equivalent terms. One milligram per liter is equal to one milligram of the substance dissolved in a liter of water.) "Sparkling water" is carbonated, either naturally or artificially, with dissolved carbon dioxide gas, while "still water" (tap water and many waters sold as drinking water) comes minus the bubbles.

If the label reads "drinking water," chances are it is tap or well water which may have undergone additional filtering or processing prior to bottling. By law, "spring water" must come from a spring (unless the "spring" is just in the company's name); it may or may not have had extra processing.

Testing the Waters

Is bottled water necessarily "better"? From a taste perspective alone, there are those who would argue this point, especially if the waters in question are all placed on equal footing—chilled and tasted in a "blind" test under controlled conditions.

A news segment on Los Angeles television station KNXT featured a blind taste comparison of bottled water and the tap water the Los Angeles Department of Water and Power serves its customers in Hollywood. The tasters rated the tap water among the best, according to the newscast.



Another taste test, this one conducted for the San Francisco Chronicle by a panel of food and water quality experts, rated Bay Area water samples. In addition to the tap waters tested was an expensive bottled water from France—which finished at the bottom, behind the tap waters. Across the continent, Consumers Union stacked 23 sparkling waters, 14 still bottled waters and one tap water against each other. According to these experts, the best tasting water was New York City tap water.

Health and Safety

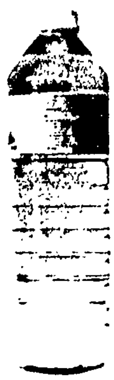
What about the health and safety questions?

"If everything's working properly, tap water and bottled water should be equally safe," says Dr. Jack Sheneman of the California Department of Health Services' Food and Drug Branch, the division which oversees the bottled water industry.

To make sure things keep on "working properly," purveyors of tap water and of bottled water both are required to meet quality regulations set by federal and state governments and must regularly report chemical, physical and microbiological test results to the state.

Underground contamination—such as by improperly used, stored or disposed of chemicals—could as likely affect bottled waters drawn from springs or wells as public supplies. The additional processing some bottled waters undergo, however, could remove some of these substances.

Bottled Water Test: Hard vs Soft Water



Overall, most of the bottled waters contain lower levels of dissolved minerals. Minerals, though, help make water palatable, and some water bottlers remove and then add back minerals to their product to improve its taste. Distilled water, which contains no dissolved minerals, is flat-tasting and not at all refreshing.

Two minerals, magnesium and calcium, contribute to a water's "hardness." Many of the bottled drinking waters in the various tests were considered "soft" (the point separating harder from softer is somewhere in the neighborhood of 70 milligrams per liter of hardness), while some of the state's tap waters — particularly those in southern California—are on the hard side.

Although it has not been proven conclusively, some health experts believe harder water is better for cardiovascular (heart) health than soft. One speculation offered is that hard water has some sort of "protective" quality that helps prevent cardiovascular disease.

Questions

1. What kind of water do people in your class prefer?

____

2. What was the least popular water? State reasons.

____

____

____

____

____

____

Water Sample Rating

Sample	Your Rating Score	Class Average Rating Score
1		
2		
3		
4		
5		

LAB 4a

Pure as the Driven Snow?

Parts per Million or Billion

Introduction

Substances dissolved in water are usually measured in parts per million or parts per billion. But how diluted is that? In this part of the lab, you will create solutions that are one part per million and one part per billion dilutions.

Different toxins or poisons are considered hazardous at different concentrations. According to the Environmental Protection Agency (EPA), the following are maximum contamination levels allowed for drinking water in parts per billion (ppb):

Arsenic	50
Selenium	10
Nitrates	10,000
Trihalomethanes (THM)	100

Materials

- 9 clear containers or one white plastic egg carton
- white paper
- tooth picks
- food coloring

Procedure

1. Put down sheets of white paper. Line up nine clear containers, (or use white plastic egg cartons). Label #1-9.
2. Put 10 drops of food coloring in #1. Food coloring is already at a dilution of 1:10.
3. Take one drop from #1 and place it in container #2. Add 9 drops water with a clean dropper and mix with a toothpick.
4. Repeat this process in each container. (example: Take one drop from #2, put in #3, add 9 drops water, stir.) Each dilution will be 10 times more dilute than the previous one.

Data

Container	Dilution
1	1:10
2	1:100
3	
4	
5	
6	
7	
8	
9	

Discussion

1. Which container was at a dilution of 1 part per million? _______
   1 part per billion? _________
2. In which container could you no longer see the color? ________
3. In the last container, was there any food coloring present? _____
   How might you prove this?

____

____

____

____

Conclusion

____

____

Pure as the Driven Snow?

Water Quality in Drinking Water

LAB 4b

Introduction

Drinking water is tested for many substances to make sure it is safe for humans. In this lab, you will be measuring the level of acidity, or pH, and the level of dissolved chlorine. Chlorine is frequently used to disinfect, or destroy potentially harmful bacteria, viruses, and other organisms in drinking water. Enough chlorine is added to leave residual amount of chlorine in the water, to continue to kill any pathogens in the pipelines that convey the water to the users.

Materials

tap water, or the water samples from Lab #3
pool or spa testing kit

Procedure

1. Fill both sides of test kit container with water from one of the samples. Add 5 drops of OTO to the chlorine test side and 5 drops of phenol red to the pH test side. Cap or cover the containers and shake gently to mix contents.
2. Hold white card or paper behind container and compare color of the liquid with the indicated colors on the container.
3. Record the chlorine level (the numbers given are in parts per million (ppm). Record the pH level.
4. Repeat procedure with each water sample.

Data

Water Sample	chlorine—ppm	pH

Results

1. Which sample had the highest chlorine level? ______ the lowest? _______ Can you explain this difference?

____

2. How does chlorine level relate to the taste test results from lab #3?______________________________

3. What are THMs? ______________________________
How do they relate to chlorine in drinking water?

____

4. A neutral pH is 7, which means a sample is neither acidic nor basic. Which of the samples was neutral? ______________
Which samples were acidic? ______Which were basic? ______
Give a possible explanation as to why they were not neutral.

____

5. The pH of clean rainwater is between 5 and 6. Give a possible explanation as to why rainwater is not neutral.

____

____

6. How did the pH of the water samples relate to the taste test results in lab #3?

____

____

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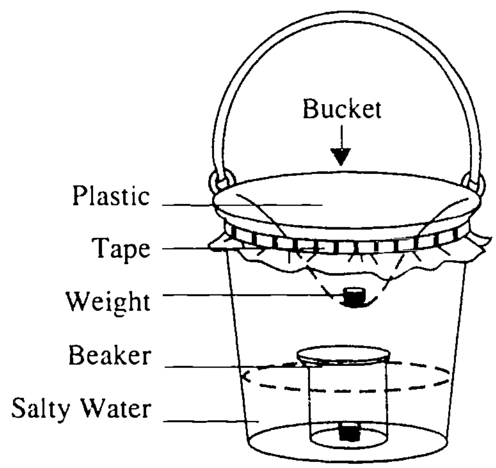
LAB 5

Water, Water Everywhere, But Not A Drop To Drink . . .

How to Build a Solar Water Purifier

Background Reading

Usable water also can be created by using solar energy techniques. There are desert cities, outside the United States, which receive drinking water from solar evaporators. Almeria, Spain, a town of 300 people gets all its drinking water from a solar evaporator. Saudi Arabia also uses some solar evaporators. Although the process is still impractical, technology is being developed to allow desert towns and cities to turn water from the ocean or other sources of salty water into fresh water. The California city of Santa Barbara is planning to build a desalination plant in response to an extended drought.



Activity

1. Follow the illustration in the Lab to set up your lab materials. The water level should be at least an inch below the top of the beaker.

2. Be sure that your plastic completely covers the top of the bucket. The plastic should sag enough when the weight is placed on it so that a cone shape is formed which points down to the open beaker. Make sure that the plastic does not touch the mouth of the beaker.

3. Place your apparatus in the heat of the sun and leave it there for a few hours.

4. During class the next day, remove the plastic covering and taste the water in the beaker.

Results

1. How does it taste? ____________ Is it fresh or salty?________
2. What was the energy source that caused the water to change states?____

____

3. What are the 3 states of water?__________________________

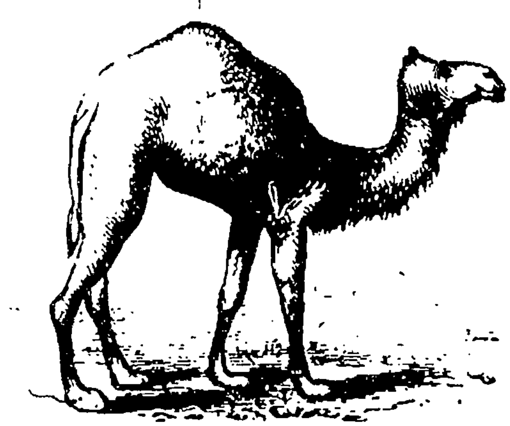
____

4. How much fresh water is there in the world? (See Water Trivia Facts Card) ______________________________________

5. Why isn't fresh water currently being distilled from ocean water for urban use?____

____

____



Water And The Environment

Teacher's Information Labs 6–9

SECTION 2

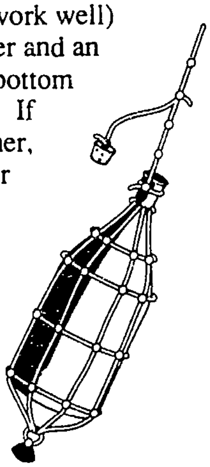
LAB 6
SURVEYING A WATER BIOME

Objective

Students will evaluate two characteristics of a fresh water ecosystem: water temperature and water clarity. Students will determine how these characteristics affect living populations.

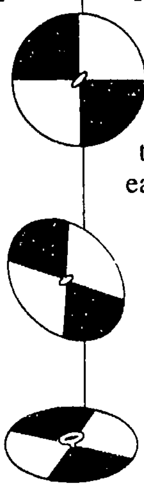
Lab Hints

If your school is near a fresh water ecosystem, (e.g. pond, stream, lake) you can use this lab as a guide to a field study. If not, you can create your own "pond" by filling a large container (plastic 5 or 10 gallon paint buckets work well) with pond water and an assortment of bottom dirt and plants. If using a container, knots on Meyer Sampler and Secchi Disk should be at small intervals. It is not necessary that students identify plants and animals by name, but rather that they have a general impression of the types of organisms present and their relative numbers.



Extension Activities

This lab may be extended to collecting samples for Lab 9: Mini-ecosystems.



LAB 7
IT NEVER RAINS IN SUNNY CALIFORNIA
Rainfall, Geography, and Vegetation Patterns

Objective

Students will identify rainfall patterns and relate them to geography, topography and vegetation patterns. Students will understand how rainfall patterns affect water supply in California.

Lab Hints

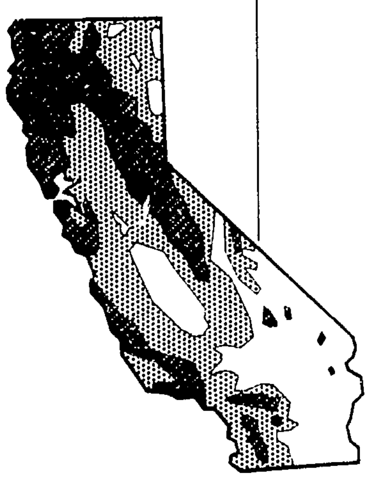
Divide the class into 6 groups. Assign 10 cities from the Precipitation Chart to each group. Each group will place a colored sticky dot or pin on the California Water Map for the rainfall amount for each city using the following categories:

Red	=	5 inches or less
Yellow	=	6-15 inches
Green	=	16-30 inches
Blue	=	over 30 inches

Using the same categories, each group will also place a colored dot on their vegetation profile chart for each of their ten cities. It would also be a good idea to have a class vegetation profile with all the cities indicated. A road map of California makes finding the location of the cities easier.

Extension Activity

Have students research how rainfall affects what crops are grown in California. Irrigation systems may also be studied. The State's CIMIS (California Irrigation Management Information System) and the use of home computers to calculate water requirements of crops is another interesting research topic.



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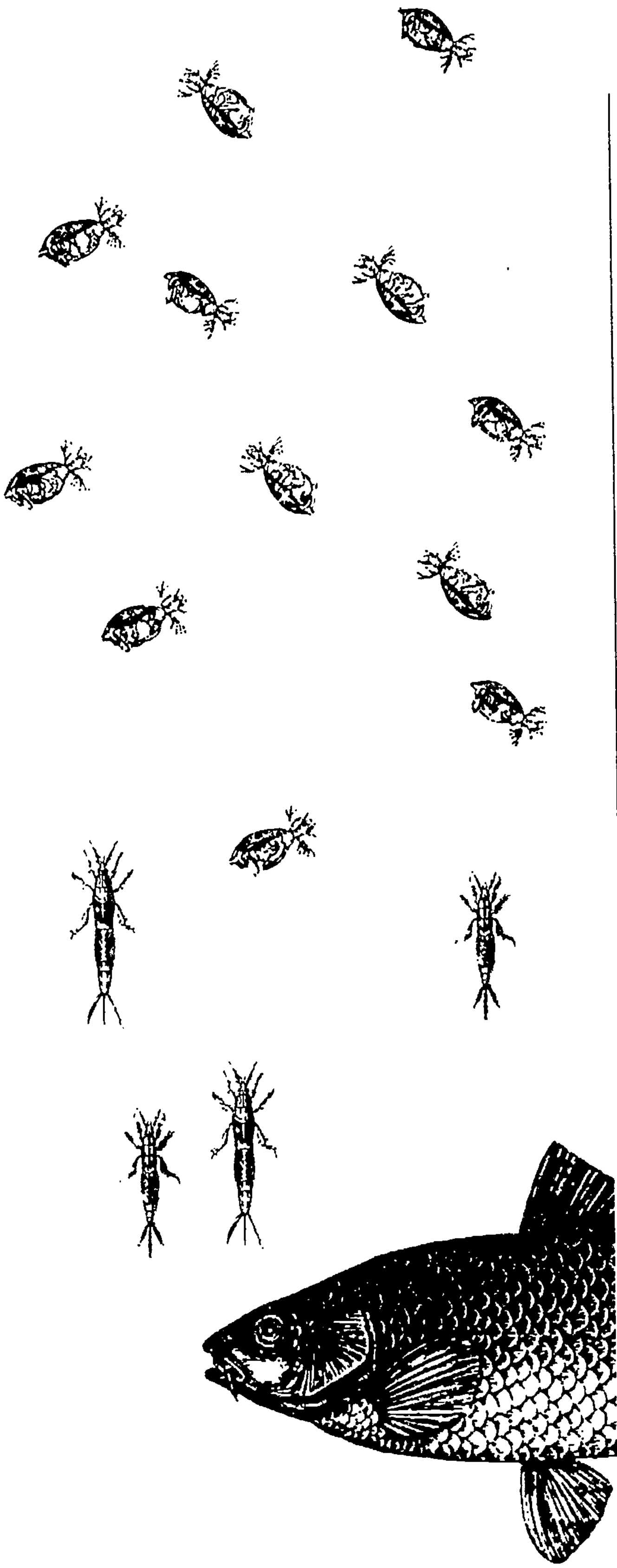


LAB 8
THIS GAME MAY BE HAZARDOUS TO YOUR HEALTH
Accumulation Of Toxins In The Foodweb

Objective
Students will understand the concept of an ecosystem, energy transfer through the aquatic food chain, and how toxic materials can enter the food chain. Students will appreciate the delicate balance of nature.

Background Information
Water quantity problems have plagued California since the days of its early settlers. Our state's massive water transportation and storage systems are testimony to the fact that California's water supplies quite often do not occur where and when they are needed most. Our water supply is sometimes a case of glut or famine, flood or drought. But all the water in the world—in the right place, at the right time—won't do a drop of good if it isn't fit to use.

True, our domestic water supplies have come a long way since the days when a glass of water might carry with it the threat of **cholera** or **typhoid**. But almost daily, the news media carry alarming stories of toxic substances threatening our ground water supplies. We've learned that our surface supplies aren't immune from exotic-sounding **contaminants.**

The very chemical used to destroy disease-causing bacteria in drinking water has given rise to a whole new problem—the formation of substances which might possibly cause cancer. The quality of our water supplies, once taken largely for granted, is becoming the focus of increasing concern.

Materials needed
1. *Layperson's Guide to Drinking Water*. Read pp. 3 and 16.

2. "Food"—white pipe cleaners and colored pipe cleaners, white and colored paper dots (two-thirds of them white, one third colored)—you can get these from the school hole-puncher. For a class of 30 students you should have a paper bag full of 600 of the white food (uncontaminated) and a bag full of 300 of the colored food (contaminated with toxics).

Activity
1. Tell the class that this is an activity about aquatic food chains. Spend some time in establishing a definition. **NOTE:** Do not tell the students what the color of the food represents until after the fish have "fed."

a. Divide the class into three groups. One group will be the water daphnia (a small freshwater animal) group (18 to 20 students). The second group (6 to 8 students) will be the insect larvae who prey on the daphnia group. The third group (2 or 3 students) will be the fish who prey on the insect larvae.

b. Hand each "daphnia" a small paper or plastic bag or other container. The bag represents its stomach (a container to hold food energy).

c. Scatter the "food" (pipe cleaners or paper dots) in the area where the activity is being conducted. The area can be the classroom if the desks or tables can be moved back, or a grassy area outside. **NOTE:** You will have to establish boundaries.

d. The "daphnia" are now instructed to go looking for food, gathering the "food" and placing it in their container or bag (stomach). At the end of 30 seconds, the "insect larvae" attack the "daphnia" and eat (collect their "stomachs") as many as possible in 30 to 60 seconds. Any daphnia caught must give up their "stomach" to the insect larvae and move to the sidelines.

e. The "fish" are now permitted to "eat" insect larvae for 15 to 30 seconds. The same rules apply. At the end of the time period, ask all students to gather together and bring whatever food bags they have with them.

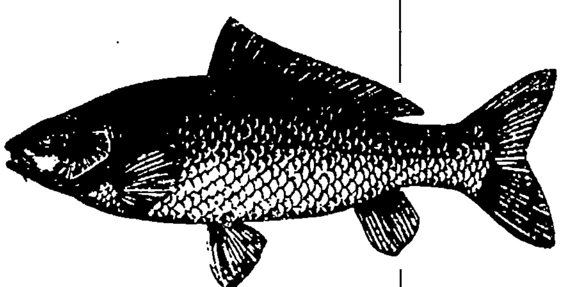
f. Identify which "animals" are still alive. The live animals are to empty their stomach(s) and count the number of white "food" pieces they have and the number of colored pieces. List on the board the species and the number of each kind of "food." Hand out data chart sheets.

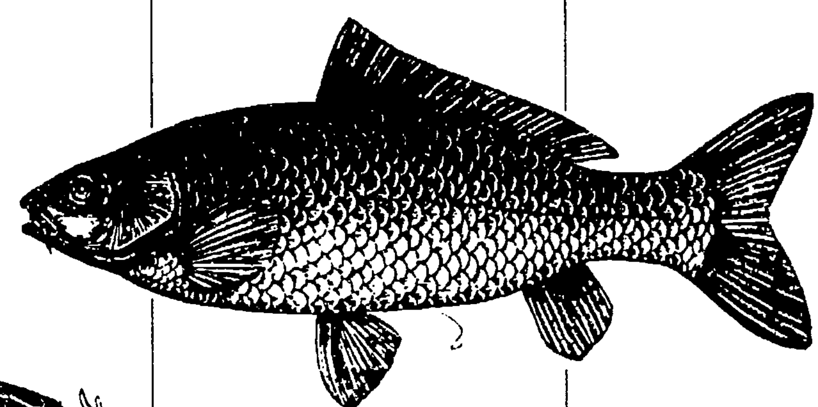
2. Inform the class that there is a toxic chemical loose in the water environment. It is poisonous, accumulates in food chains and stays in the environment for a long time. In this activity, all of the colored pieces of "food" represent the poison. All of the "daphnia" that were not eaten by the "insect larva" may now be considered dead if they have any colored food pieces in their food supply. Any "insect larvae" with a food supply that exceeds 50 percent of colored food pieces will also be considered dead. Any "fish" with a high concentration of the toxic chemical may be able to survive, but its ability to ward off disease, produce offspring, find and catch food may be limited.

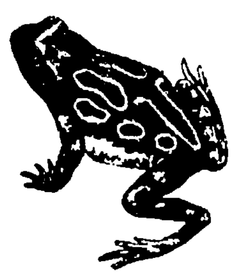
3. Discuss the activity with the class and ask students for their observations about how the food chain works and how the toxic chemicals can affect it.

Extension activity

Research: point vs. non-point pollution, bioaccumulation of toxins.







LAB 8
IT'S A SMALL WORLD AFTER ALL
A Water Mini-Ecosystem

Objective

Students will set up aquaria and study variable influences on daphnia, a small freshwater animal commonly used as food for aquarium fish. Students will realize how complex an ecosystem is to maintain artificially and to learn how variables can affect an ecosystem.

Materials needed

1. plankton net or a large jar
2. white porcelain sorting trays or equivalent
3. eye droppers
4. hand lenses
5. light source
6. thermometers
7. 1 to 2 gallon aquaria (or 1 gallon jars) with glass tops
8. spring water, filtered pond water, or tap water which has been treated with antichlorine compound (purchased in pet shop) and allowed to stand for one week. The pH should be about 7.
9. **Daphnia magna**

Activity

1. *Daphnia magna* can be purchased from a tropical fish supply house or collected.
2. If collecting daphnia use the following procedure: Use the plankton net and jar to collect several samples of zooplankton by pouring jarfuls of pond water through the net. Empty the concentrated zooplankton from the small bottle on the net into a sorting tray. With the eye dropper and a hand lens, select the largest daphnia (most high school biology texts have pictures of daphnia) that have young in their brood pouches (seen dorsally and posteriorly to the eye). Put them in the jar together with water from the pond and some material from the pond surface and bottom.

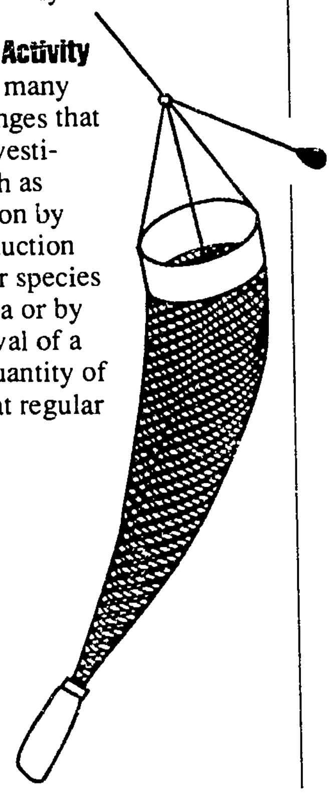
When you have collected a number of daphnia (several for each container you intend to set up), take them back to the classroom and allow them to become acclimated to the classroom environment for a day or two. You might consider using aquarium heaters in each of your culture containers to maintain a constant temperature of 22°C (72°F).

Once the mini-ecosystems are functioning and in balance, you can have your student teams change one variable for their system. One or more systems can be maintained as controls. You may want to assign the variable change or else let each team pick the variable. The results of all these changes should be recorded and compared with that of your control culture. The following are suggested changes. The students should observe the daphnia regarding the effect of the variable on change of daphnia color, swimming habits, etc.

1. **Aerate** the culture
2. Increase or decrease the food supply.
3. Increase the **hardness** of the water by adding magnesium and/or calcium salts: slowly, quickly.
4. Increase or decrease the pH by adding 0.1 M acid or base slowly over a few days or quickly over a few hours
5. Cut off the light source to reduce the DO (dissolved oxygen) level.
6. Raise or lower the temperature of the culture, slowly then quickly.

Extension Activity

There are many other changes that can be investigated such as competition by the introduction of another species of daphnia or by the removal of a certain quantity of daphnia at regular intervals.



Surveying A Watery Biome

Water Temperature

LAB 6a

Background Reading

Air temperature determines, to a large extent, the surface water temperature. An ordinary thermometer can be used to take the water temperature, but the reading must be taken in the shade. (Your hand can provide the shade.)

Temperature plays an important role in determining the species of organisms which can live in a particular body of water, and because most aquatic organisms are cold blooded, their temperatures vary. Although students will not be field sampling water temperatures from ponds and lakes it is important to know that water temperature also affects dissolved oxygen levels.

The Meyer Sampler Bottle is the simplest and least expensive method to use for bringing up a sample of water so its temperature can be measured.

Question

How is water temperature related to depth?

Materials needed

1. one thermometer

2. one Meyer Sampler, with calibrated cord marked in meters or feet. Instructions to build a Meyer Sampler. (see below)

Activity

1. Three things are important when using the thermometer:

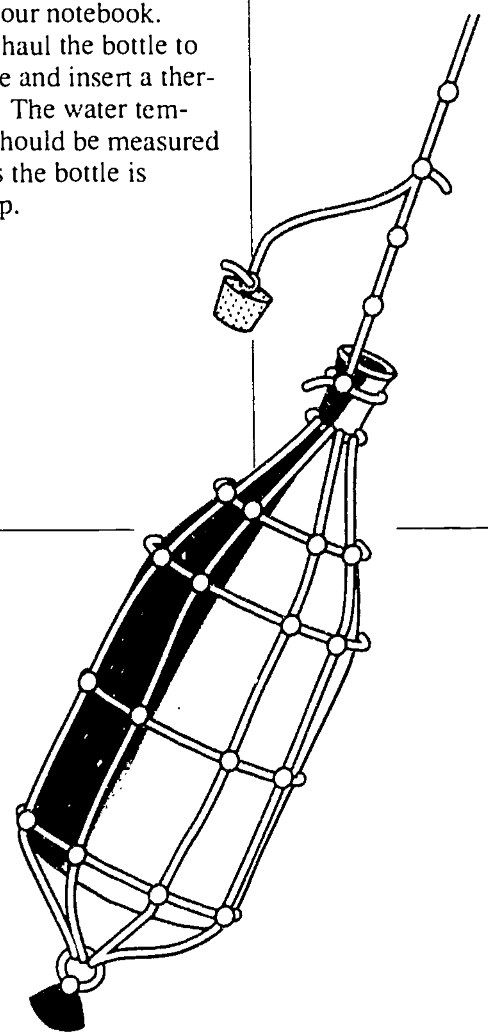
a. Shade the thermometer from the direct rays of the sun.

b. Immerse the thermometer bulb in the water and let it remain there long enough to allow it to come to the temperature of the water sample.

c. Read the thermometer while the bulb remains in the water.

2. Measure the surface temperature by immersing the temperature bulb in the water. Record the temperature and location.

3. Following your teacher's directions, use the Meyer Sampler. The Sampler should be lowered with the stopper in place. At the proper depth the cork is opened by a jerk on the cord. Wait a few seconds for the bottle to fill. Record the depth in your notebook. Carefully haul the bottle to the surface and insert a thermometer. The water temperature should be measured as soon as the bottle is brought up.



Instructions for making Meyer Sampler

Obtain a pint or quart bottle which can be tightly corked.

Obtain some strong nylon string and fashion a net around the bottle and attach a fishing weight to the net at the bottom of the bottle.

Connect a cord to the bottle's neck and fasten the cork to it.

You can calibrate the cord by tying single knots in it at foot or meter intervals so you will know at what depth the water sample was obtained.

When the sampler is lowered into the water, it is corked. At the desired water depth, the cord is given a sharp tug to dislodge the cork so the water may flow into the sampler.

4. Repeat Step 3 two more times, recording the depth, temperature and numbering your samples (1,2 or 3).

5. Average your temperature readings and record them.

6. If you are to take many readings over days or weeks, you will be more accurate if readings are made at the same time of day.

Hypothesis

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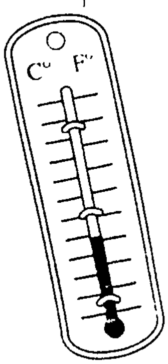

Record

Air Temperature	Location
Water Temperature Trial 1 Location	Depth
Trial 2 Location	Depth
Trial 3 Location	Depth

Results

1. Did the water temperature increase or decrease as depth of water increased?

____

2. How does water temperature affect the amount of dissolved oxygen in water? (Hint: which goes flat first, a glass of warm coke or cold coke?)

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3. How might water temperature affect the organisms living in body of water?

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Conclusion

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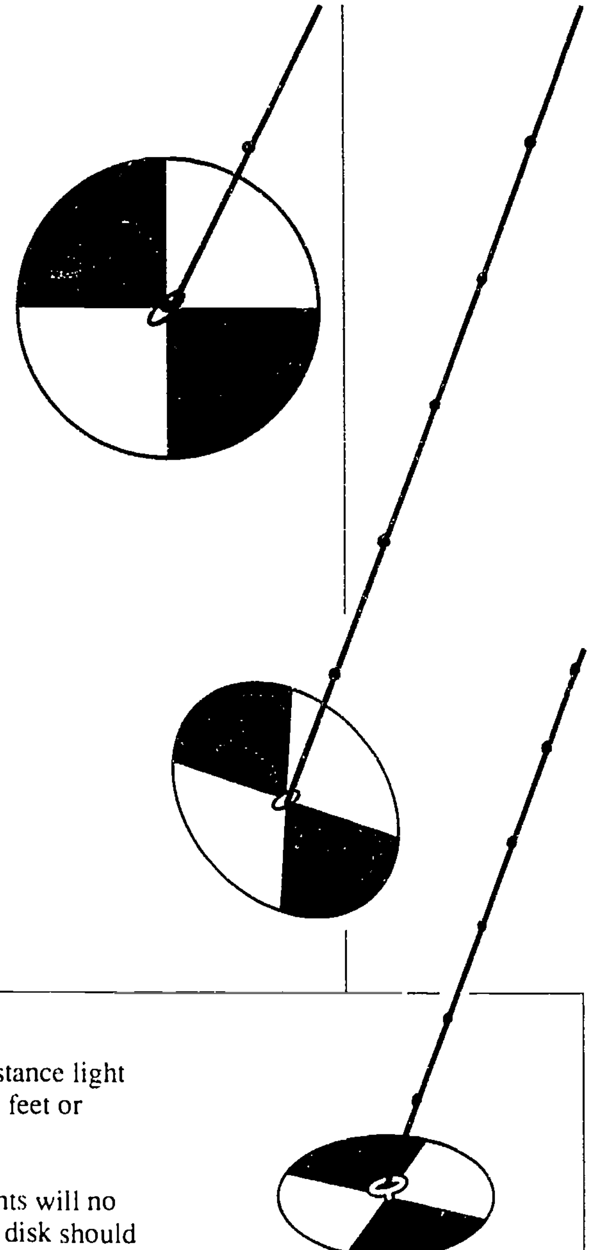
Surveying A Watery Biome

Water Clarity

LAB 6b



Background Reading

The presence of different kinds of organisms living in an aquatic ecosystem is determined by various aspects of water quality.

It is important to remember that physical, chemical and biological factors all interact. For example, an overgrowth of **algae** caused by sewage runoff may cause a severe reduction of dissolved oxygen in the water, which will threaten the survival of various aquatic animals. It is important to analyze as many aspects of the aquatic environment as possible to get a clear view of what is occurring.

The presence of some aquatic plants and animals may not be a clearly reliable indicator of what is happening, because some plants and animals can grow in polluted, as well as an unpolluted, environment. However, biological data, along with physical data, are an important part of the total picture.

This Lab will enable you to gain experience in using your senses to look at an aquatic ecosystem. Some equipment will be used as an extension of your senses. Secchi Disk readings can give an indication of the amount of productivity of living materials in water. In very productive waters, light penetration will be limited by the presence of billions of tiny organisms. Clear water is an indication of low productivity of living organisms.

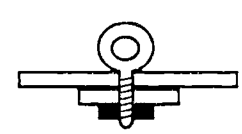
Question

How is water clarity related to productivity of living organisms in a fresh water habitat?

Instructions for making a Secchi Disk

The Secchi Disk is used to determine water clarity by measuring the distance light penetrates into the water. The disk is lowered with a line marked off in feet or meters until it just disappears from sight.

This is known as the Light Compensation Level, the point at which plants will no longer grow from the bottom of the pond. The conditions for using the disk should always be standardized: clear sky, sun directly overhead, with readings taken in the shade.



The Secchi Disk is a circular plate 20 cm in diameter. It can be made out of 1/4" or 3/8" marine grade plywood or 18 gauge metal. The upper surface of the disk is divided into four equal pie shapes, with each quadrant painted alternately black and white with semi-gloss enamel paint. The undersurface is painted black. The center of the disk is drilled and a weight and eye bolt are attached. A line which has been accurately calibrated in meters is attached to the eye bolt.

Materials needed

1. Secchi Disk
2. hand screen, nets, kitchen sieve, coffee can and hand lens
3. pans to hold collected species

Procedure

1. Examine a sample of pond water. Either observe small container of water with a hand lens or look at drops of water under a microscope.

Record your observations

2. Use the Secchi Disk to determine the limits of visibility in the water. Lower the Disk until it just disappears from view and record the depth. Lift the Disk and record the depth at which it reappears. The average of the two readings is the limit of visibility. Take at least three sets of readings and record each of them to the nearest 1/4 of a meter. Average your answers below.

Record

Lower Secchi Disk	
1. Depth at which Disk disappears	
Depth at which Disk appears	
Average of two depths	
Do this procedure a total of three times	
2. Depth at which Disk disappears	
Depth at which Disk appears	
Average of two depths	
3. Depth at which Disk disappears	
Depth at which Disk appears	
Average of two depths	
4. Average all three answers	

Questions

1. Was the water clear or cloudy? ____________________

2. What organisms are present?

____

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3. How organically productive is this water?

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Conclusion

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It Never Rains In Sunny California

Rainfall, Geography, And Vegetation Patterns

LAB 7

Background Reading

Rainfall is controlled by such factors as wind direction, elevation, and temperature. In California, the northern part of the state receives more rainfall than the southern part of the state.

Since more people live in the south and most of the food is grown in the arid central and southern areas, there is an imbalance. Distributing this water fairly, without harming the environment, is the challenge of your generation.

Your water supply comes through the hydrologic cycle, in a never-ending process. Water is carried from the ocean by evaporation of moisture, forming clouds. As these clouds move through the atmosphere, they rise higher. There they are cooled, causing the moisture to fall to the land in the form of precipitation—dew, rain, hail, sleet or snow. This moisture is either absorbed into the ground, evaporated, or eventually collected in streams and rivers and returned back to the ocean where the cycle starts again.

In California, air flowing east meets mountain ranges, is forced up and cools, loses its ability to hold water and therefore rain or snow falls.

Questions

1. Where does precipitation come from?

   ____

2. Where are the areas of highest rainfall? ____________________

   Lowest rainfall? ______________________________

3. Does elevation influence rainfall?____________________

4. Find two cities or communities that are at or near the same elevation. How does the rainfall in the two cities differ?

   ____

   ____

5. How does the amount of rainfall affect streams, lakes, and ground water supplies?

   ____

   ____

6. How does the amount of rainfall affect what plants grow in a location?

   ____

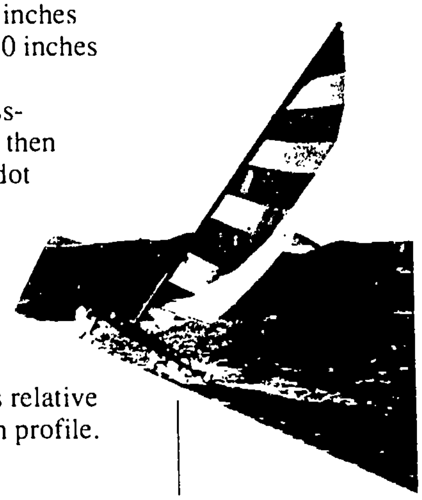
   ____

Materials Needed

1. Water Map (cellophaned or laminated)
2. California Precipitation Chart
3. Geographic Cross Sections of CaliforniaVegetation with Profiles
4. Water Soluble markers, adhesive dots, or stick pins
5. Road map of California (optional)

Activity

1. You will be divided into six teams using materials provided in this Lab. Each team will work from a copy of the vegetation profiles and chart of precipitation levels.
2. Each team will be assigned 10 cities with their rainfall amounts.
3. Place a colored dot or pin on the map to indicate the amount of rainfall of each city.
   - Red = 5 inches or less
   - Yellow = 6-15 inches
   - Green = 16-30 inches
   - Blue = over 30 inches
4. Refer to the cross-section map and then place a colored dot for each city on its appropriate location on a vegetation profile. This will indicate rainfall amounts relative to the vegetation profile.



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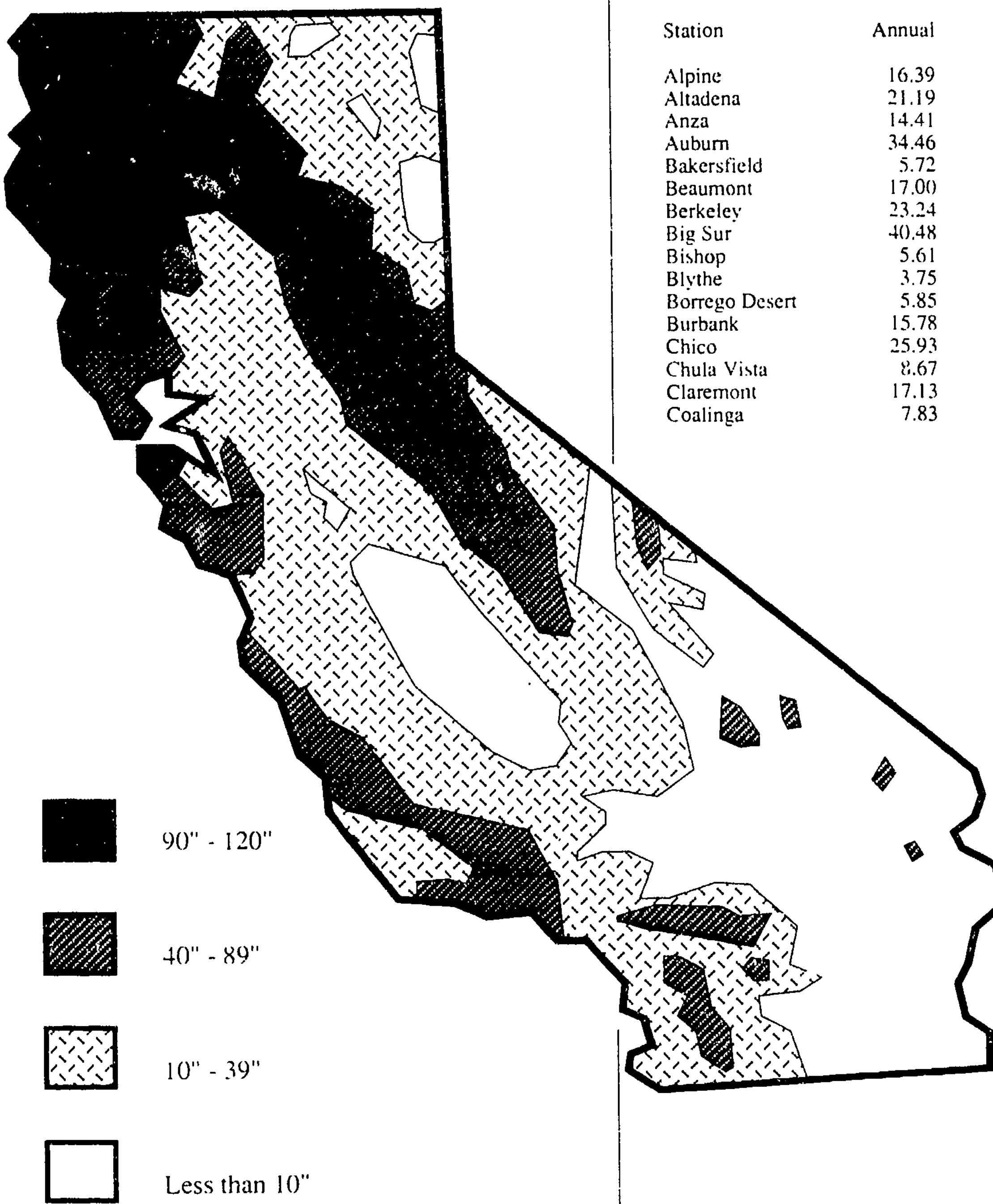
California Precipitation Chart



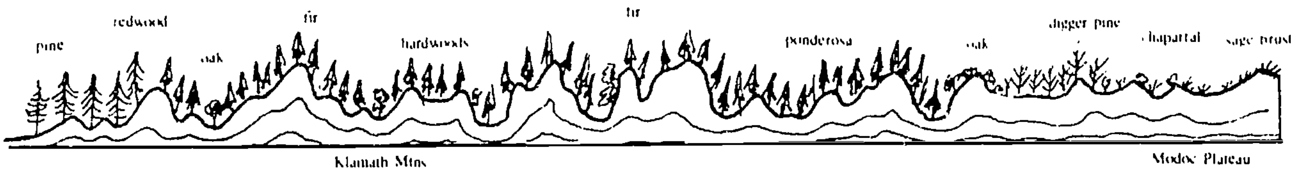
Average Yearly Precipitation

Station	Annual
Alpine	16.39
Altadena	21.19
Anza	14.41
Auburn	34.46
Bakersfield	5.72
Beaumont	17.00
Berkeley	23.24
Big Sur	40.48
Bishop	5.61
Blythe	3.75
Borrego Desert	5.85
Burbank	15.78
Chico	25.93
Chula Vista	8.67
Claremont	17.13
Coalinga	7.83
Covina	17.24
Culver City	14.09
Death Valley	2.03
Downey	14.38
Downieville	62.70
El Centro	2.35
Escondido	14.53
Fort Bragg	39.30
Fresno	10.52
Garberville	57.09
Gasquet Ranger Station	94.22
Half Moon Bay	25.22
Helmet	11.51
Idyllwild	25.39
King City	11.25
Lakeport	30.04
Lemon Cove	13.47
Long Beach	11.54
Los Angeles	14.85
Modesto	11.70
Monterey	18.35
Muir Woods	36.36
Needles	4.39
Oakland	18.03
Oxnard	14.50
Palm Springs	5.20
Petaluma	24.02
Placerville	36.99
Redding	40.95
Redlands	12.89
Sacramento	17.87
San Diego	9.32
San Francisco	19.71
San Jose	13.86
Santa Barbara	17.70
Stockton	14.40
Torrance	13.13
Turlock	11.39
Twentynine Palms	3.89
Vacaville	24.29
Van Nuys	15.99
Visalia	9.86
Whittier	14.51
Yosemite	36.06

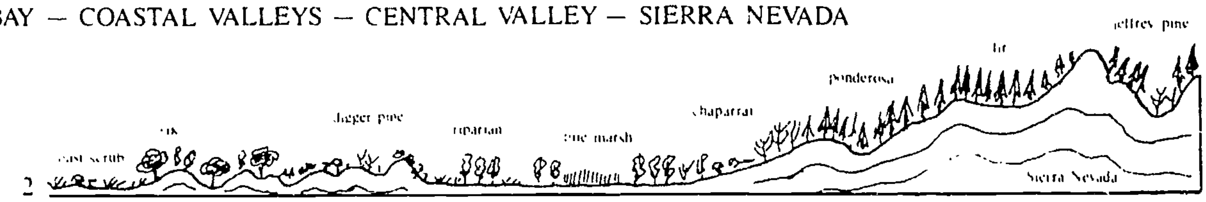
Source: California Almanac

Geographic Cross-Sections of California with Vegetation Profiles

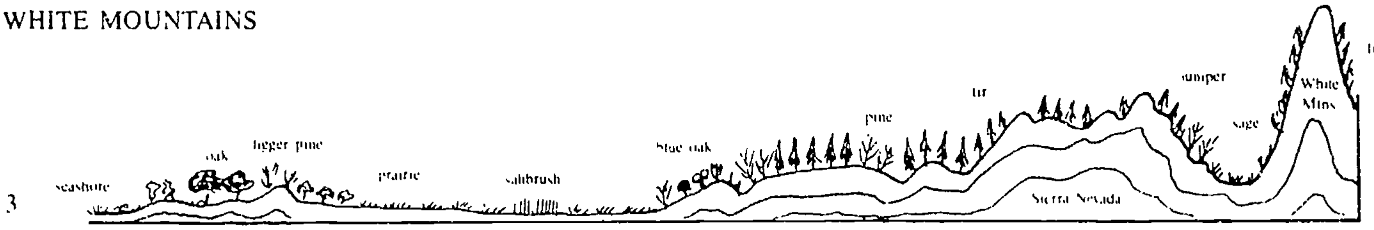
TRINIDAD HEAD — TRINITY ALPS — MODOC PLATEAU



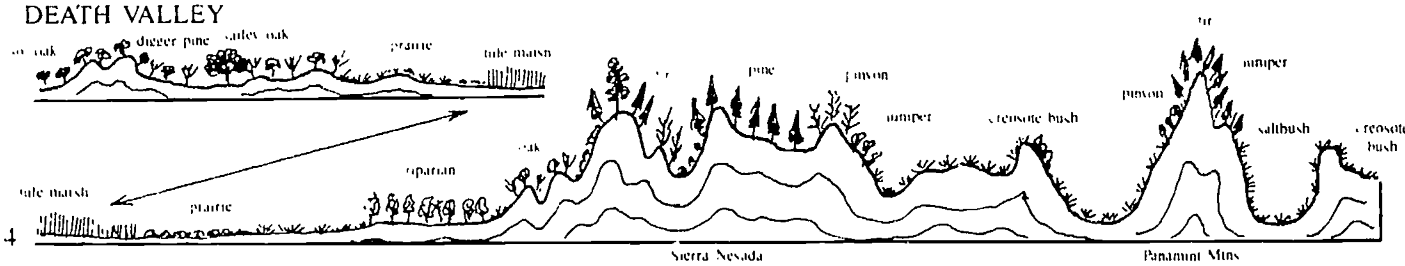
TOMALES BAY — COASTAL VALLEYS — CENTRAL VALLEY — SIERRA NEVADA



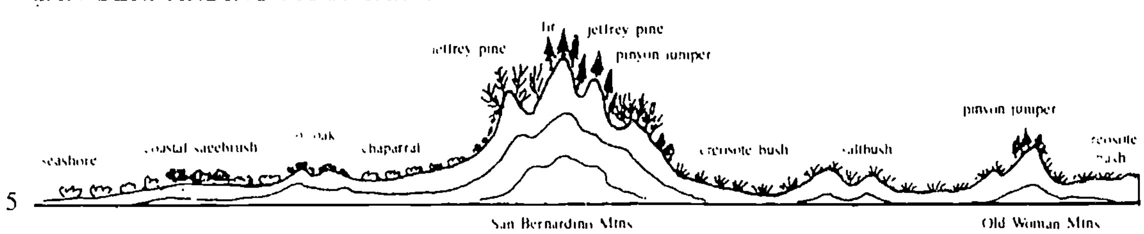
PAJARO VALLEY — GABILAN RANGE — SAN JOAQUIN VALLEY — SIERRA NEVADA — OWENS VALLEY — WHITE MOUNTAINS

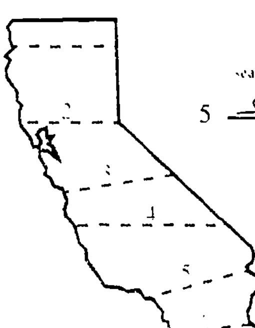


SAN SIMEON — SALINAS VALLEY — SAN JOAQUIN VALLEY — SIERRA NEVADA — OWENS VALLEY — DEATH VALLEY

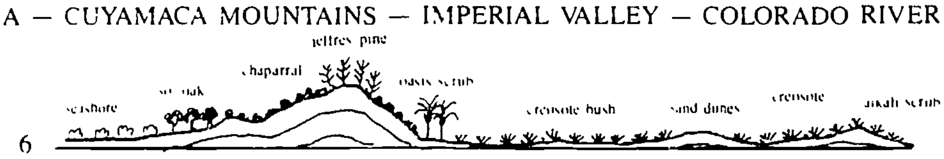


SAN PEDRO BAY — SAN BERNARDINO MOUNTAINS — OLD WOMAN MOUNTAINS — COLORADO RIVER





POINT LOMA — CUYAMACA MOUNTAINS — IMPERIAL VALLEY — COLORADO RIVER

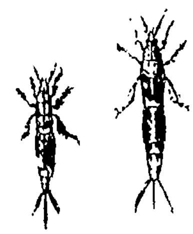


LAB 8

This Game May Be Hazardous To Your Health

Accumulation of toxins in the foodweb

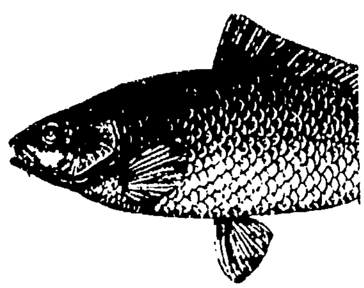
Data Chart	Beginning #	Ending #	Stomach Contents	Live End #
Daphnia				
Insect Larvae				
Fish				



Questions

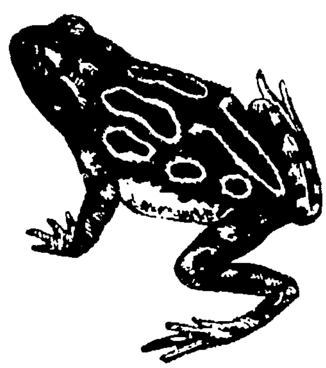
1. Describe the foodweb in this aquatic ecosystem, including information about the proportion of each organism.

2. How did the toxin affect the Daphnia? the larvae? the fish?



3. What do you predict will happen in this foodweb over time?

4. How can toxins be removed from an aquatic ecosystem?



It's A Small World After All

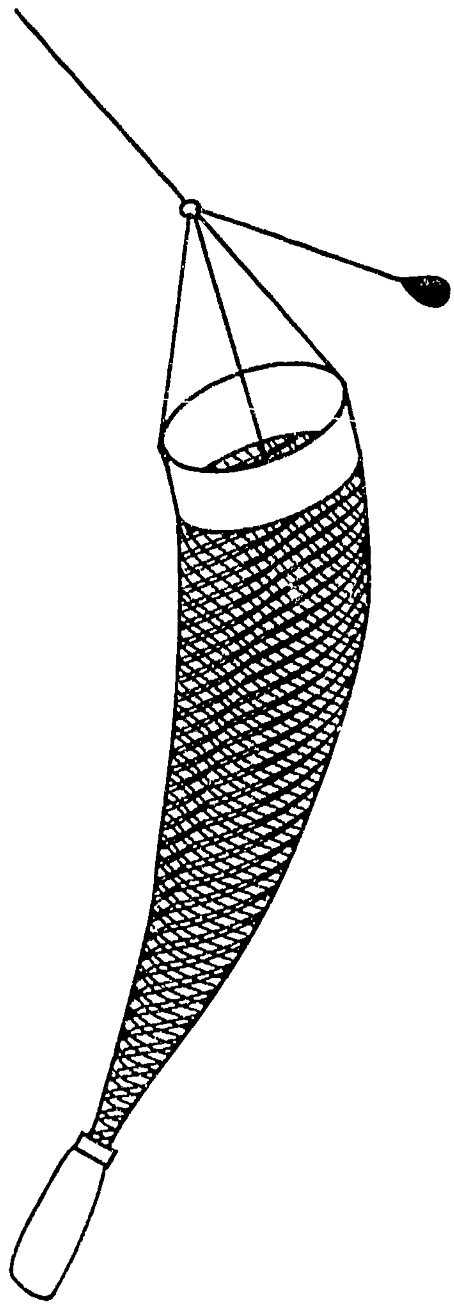
A Water Mini-Ecosystem

LAB 9

Background Reading

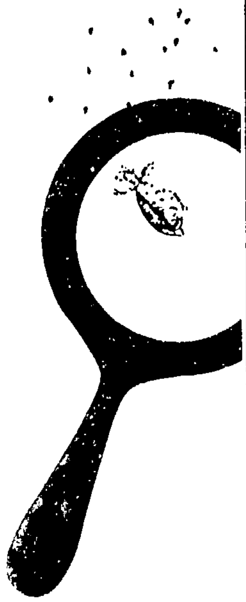
Often it is not possible or practical to study an aquatic ecosystem (i.e. pond or stream) in the field. On these occasions, it is possible to create a miniature, aquatic ecosystem in the classroom. There are a number of advantages and disadvantages involved in doing this. The main thing to remember in this study is the limitations of application to an actual aquatic environment when dealing with an artificial one.

There are many ways to set up an ecosystem for study. In this experiment we will limit ourselves to one species, *Daphnia magna*. There are a number of reasons for doing this, foremost of which is the ease of raising and observing *Daphnia magna*. In this experiment you will study the effects of changing various environmental conditions on daphnia magna.



Question

How will variables in aquarium environment affect a population of *Daphnia magna* (water fleas)?



Materials needed

1. **plankton** net or a large jar
2. white porcelain sorting trays or equivalent
3. eye droppers
4. hand lenses
5. light source
6. thermometers
7. 1 to 2 gallon aquaria (or 1 gallon jars) with glass tops
8. spring water, filtered pond water, or tap water which has been treated with antichlorine compound (purchased in pet shop) and allowed to stand for one week. The pH should be about 7.
9. Daphnia magna

25

Activity

1. Place several mature Daphnia into your team's aquarium (jar) along with a 1/2 pint (250ml) of pond or stream water rich in algae and other microorganisms. Repeat this addition of "rich" pond water every week. Keeping the aquaria well-lighted, to keep a growing source of algae present, should allow the Daphnia population to increase to its maximum in about a week. Remember to cover the aquaria with glass to prevent introduction of unwanted materials and retard evaporation.
   NOTE: If "skin" develops on the water surface, skim it off or change the water.

2. When all of the cultures are doing well (the population is increasing), they may be considered separate, closed ecosystems. To determine if the systems are indeed balanced, count the Daphnia every three days or so over several weeks. This should give you an approximate idea of when a balanced state has been reached in each of your cultures when the population level is steady.

3. Now, what happens to the Daphnia population in each culture when you change various conditions? The results of the variable your team will introduce into your aquarium should be recorded and compared to that of a control culture your teacher will keep. The following are some of the possible variables:

   a. Aerate the culture.

   b. Increase or decrease the food supply.

   c. Increase the hardness of the water by adding magnesium and/or calcium salts: slowly, quickly.

   d. Increase or decrease the pH by adding 0.1 M acid or base slowly over a few days or quickly over a few hours. Especially note effects on population levels and heartbeat rate.

   e. Cut off the light source to reduce the DO (dissolved oxygen) level. Note the effect of this change on Daphnia color, swimming habits, population and carbon dioxide levels.

   f. Raise or lower the temperature of the culture, slowly, quickly. Note changes in heartbeat, population levels, DO level, swimming habits, etc.

Hypothesis

27

Data

Design a chart to record your data.

Questions

1. What happened to your Daphnia culture when you changed your variable? ____________________

____

2. How do you think the variable affected the Daphnia population?

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3. Get results from at least one other group. How did their variable affect the Daphnia population?

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Conclusion

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SECTION 3

Water And People

Teacher's Information Labs 10-12

LAB 10
WHERE DOES ALL THE WATER GO?
Distribution in California

Objective

Students will locate major rivers and man-made water ways in California and understand how far water is transported for urban and agricultural use.

Lab Hint

Students will use the California Water Map to answer questions on the worksheet. Since not all students can use the map at once, we suggest labs 10-12 be run concurrently with one-third of the class working on each one, then moving on to the next. This can be done with lab stations at different places in the classroom.

Extension activities

Have a student trace a drop of water from its source in California to his or her home. Ask your local water district for information about local water sources.

LAB 11
I CAN MAKE A DIFFERENCE!
Water Conservation

Objective

Students will become aware of how much water different activities require and develop a personal water conservation plan.

Lab Hints

Before beginning this activity. have the class design a chart to record the amounts of water used by each student for each activity. Post this chart where all have access to record results. Discuss ways water can be conserved:

Turn off the tap while brushing your teeth.

Don't run the water while shaving.

Only run full dish and clothes washers.

Wash cars with a bucket and spray nozzle.

Sweep outside areas rather than hosing them off, etc.

Extension Activities

Have students graph water use before and after conservation plans. Have students calculate how much water could be saved statewide if everyone followed their plan.

LAB 12
THE MUD MYSTERY...
"I CAN SEE CLEARLY NOW"
A Water Treatment Inquiry

Objective

Students will understand one aspect of water treatment: flocculation.

Reading

Pages 8-11, *Layperson's Guide to Drinking Water*

Lab Hints

If balances are not available to all students, premeasure alum into 112 gram portions. Cut litmus paper into small squares for testing water. Students will have trouble deciding why the alum and ammonia causes the dirt particles to form floc and fall to the bottom of the container. Use the inquiry method of questioning to have students hypothesize how flocculation occurs. Refer them back to pages 8-11 in the *Layperson's Guide to Drinking Water*.

Extension Activities

Have students agitate the alum jar to see if this speeds up flocculation. Have students review other parts of the water treatment process.

Possible Research Project

Use of gray water in cities. Difference between Secondary and Tertiary treated water. Contact your local water treatment plant for a speaker or possible tour.

Where Does All The Water Go?

Distribution In California

LAB 10

Refer to California Water Map for answers.
The following worksheet can be assigned as group or individual class work.

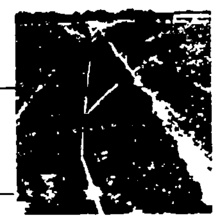
1. List the sources of water shown on the map that are within 50 miles of your school.

2. What federal water source is nearest your school?

3. Locate the Sacramento-San Joaquin Delta and describe where it begins and ends.

4. How many of California's rivers are classified "Wild and Scenic?"

5. What is the largest reservoir in the State Water Project (SWP) system?



6. Trace the path of water from the northernmost part of the SWP to the southern end.

7. What California industry is the single largest user of California's developed water?

   What percent is this of the state's total water runoff?

8. The Sacramento-San Joaquin Valley and the Imperial Valley are two major agricultural areas in California. How do their water sources differ?

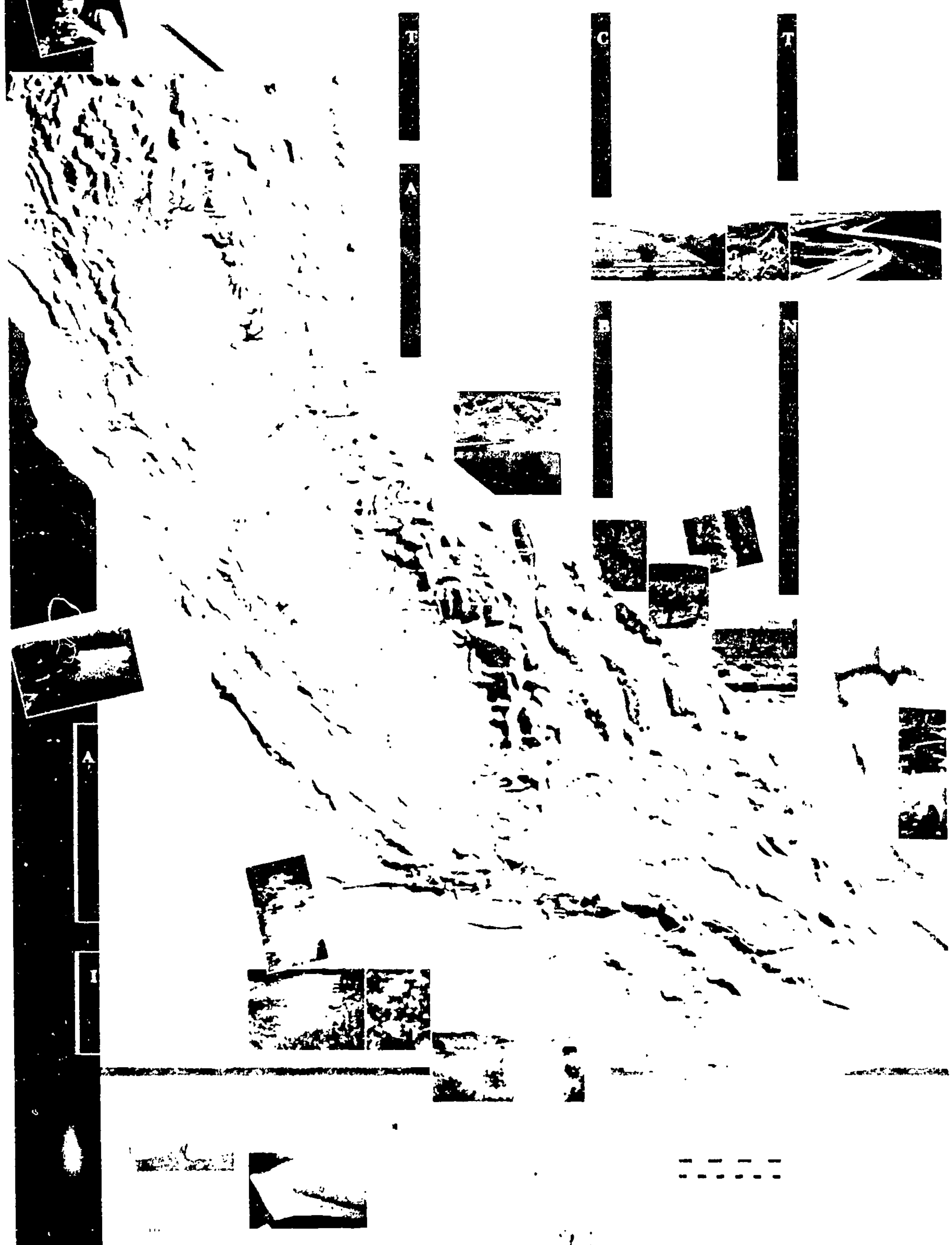
9. Where does the city of San Francisco get its water?

10. What water source do San Diego and the Imperial Valley have in common?

11. How far does the Owens Valley water flow from its source to Los Angeles?

12. What are some benefits Californians receive from our well-managed water supply?

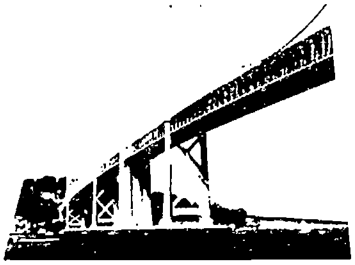
California WATER MAP



Project Water Science

Water Education Foundation

Answers to the California Water Map Worksheet



San Francisco Bay.

1. Answers will vary.

2. Answers will vary.

3. The Sacramento-San Joaquin Delta begins where the Sacramento River branches out north and east of San Francisco and ends south of Stockton. It empties into San Francisco Bay.

Wild and scenic river in northern California.

4. There are ten wild and scenic rivers in California: all of the Smith, parts of the Klamath, Trinity, Van Duzen, Scott, Eel, Salmon, Feather, American and Tuolumne Rivers.

5. The largest reservoir in the State Water Project is Lake Oroville.

6. The SWP flows from Lake Oroville south through the Feather River to the Sacramento, through the Sacramento-San Joaquin Delta, splits to form the South Bay Aqueduct and the California Aqueduct which terminates at Lake Perris east of Los Angeles.

Agriculture is California's largest water user.

7. The largest user of California's developed water (in canals and reservoirs behind dams) is agriculture (83%). Agriculture uses 31% of the state's total runoff.

8. The Sacramento-San Joaquin Valley is richly supplied with water from many rivers draining into the valley. The Imperial Valley must import water from the Colorado River.

9. San Francisco gets its water from the Hetch Hetchy Reservoir in the Sierra via the Hetch Hetchy Aqueduct.

10. San Diego and the Imperial Valley both get water from the Colorado River.

11. The Los Angeles Aqueduct is approximately 240 miles long.

12. Californians benefit by having water managed for: irrigation, flood control, fish and wildlife support, improvement of navigational waterways, drinking water, water quality control, recreational opportunities, generation of clean hydroelectric power.

LAB 11

I Can Make A Difference!

Water Conservation

Background Reading

California's growth has historically revolved around the challenge of developing and distributing water—the state's "liquid gold." As in most of the semiarid western United States, the establishment of urban, industrial and agricultural centers has always hinged on the ability to obtain a dependable water supply.

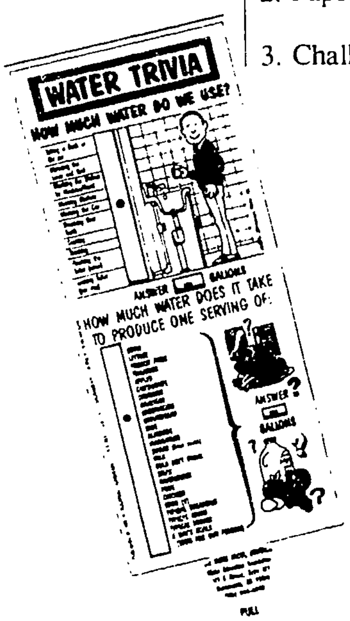
For over a century California has found its large underground reservoirs to be one of its major sources of water.

Ground water currently accounts for about 40 percent of all the water used in this state. The water pumped from California's underground basins has been one of the most vital factors in the development of California as the nation's leading agricultural producer and its most populous state. Early California settlers were able to live in many parts of the state because they could sink wells into plentiful ground water supplies.

When agriculture, business, and industry began to flourish, pumped ground water was a major water resource. Then, when pumping costs increased and the **water table** dropped, supplemental surface water began to be imported from other parts of the state. Even though most of California's ground water and surface water is used for irrigation, personal water conservation in landscaping and other urban uses by a majority of Californians can make a difference.

Materials Needed

1. Water Trivia Facts Card
2. Paper and pencils
3. Chalkboard



Follow-up

Did you have to change your lifestyle?________________

Did your attitude change?_____

What activity of yours requires the most water?

____

How much water could be saved if everyone in California followed your plan?

____

____

____

Activity

1. Estimate the amount of water you individually use each day in various activities. Use questions on Water Trivia game as a guide. Write your estimates on the chalkboard for reference.

2. Monitor your personal use of water for a day. You should write each event down on paper, for example: numbers of times you drank at the water fountain, washed your hands, flushed toilets, ate certain kinds of foods, etc. Use the Water Trivia Facts Card to determine the number of gallons of water used for each of the events listed.

3. The class should compare the estimates of water used to the actual water used.

4. Add all the gallons used by the whole class and then calculate the average by dividing the class total by the number of students. Individual students can then compare personal water consumption with the class average.

5. Come up with ways that your personal consumption of water could be reduced in times of drought. Devise a conservation plan.

6. Follow your conservation plan for at least two days.

The Mud Mystery... "I Can See Clearly Now"

A Water Treatment Inquiry

LAB 12

Question
How do water treatment chemicals clean water?

Read
pp. 8-11, *Layperson's Guide to Drinking Water*

Materials
2 liters of muddy water
2 clear glass or plastic containers
alum (112 grams per 1 liter)
ammonia
dropper
red litmus paper

Procedure
1. Shake muddy water well to distribute particles.
2. Divide muddy water into 2 clear containers. Label one "Control."
3. To the other add 112 grams alum. Next add a few drops of ammonia so that the water changes red litmus paper to blue.
4. Test after each drop with a small piece of paper. Stir or shake each container. Measure the time required for the water to clear in each container.

Hypothesis
____
____
____
____
____

Data Control — time to clear	seconds
Alum water — time to clear	seconds

Results
1. In which container did the small particles settle rapidly to the bottom? ____________________
2. How do you explain these results?
____
____
____
3. What further steps are taken in water treatment?
____
____
4. Which of these is the most important?
____
____

Conclusion
____
____
____
____
____
____
____

Glossary

aerate
to expose to or supply with air

aerobic
"with free oxygen."

algae
aquatic one- or multi-celled plants (such as kelp and other seaweeds).

anaerobic
"without free oxygen."

calibrate
to adjust or standardize a measuring instrument

cholera
an acute, often fatal disease which can be spread through sewage-contaminated water

climate
conditions, such as temperature, precipitation and winds, which prevail in a particular region

cold-blooded
having a body temperature that varies with the external environment

contaminant
anything that makes a substance, such as water, unfit for use (contaminants of water can include raw sewage, oil or hazardous chemicals)

control
a standard of comparison for checking or verifying the results of an experiment culture a growth or colony of microorganisms in a nutrient medium (special food)

daphnia magna
a small freshwater animal, some species of which are used as food for aquarium fish

dissolved oxygen
oxygen, the gas, dissolved in water is important for the decomposition of organic waste (such as sewage) in water; also crucial to the survival of fish and other organisms living in a body of water

distill
to purify by evaporating and then condensing a liquid, such as water ecosystem interaction of living things to their environment

environment
the total physical surroundings of an organism or group of organisms

floc
large, fluffy particles formed when a compound, usually aluminum sulfate, is added to water, causing smaller suspended particles to clump together. Flocculation (the act of making floc) is often an important step in water treatment (making water suitable and safe for drinking and household use)

ground water
water which fills the pores (spaces) between rocks and other materials found beneath the earth's surface. Ground water supplies about 40 percent of California's water needs, while surface supplies (such as rivers and reservoirs) supply the rest.

hardness
amount of calcium and magnesium dissolved in water 'Hard" water makes cleaning tasks more difficult (soap doesn't "suds" the way it does with "soft" water), but some scientists believe drinking hard water contributes to healthier hearts.

hydrologic cycle (also called "water cycle')
nature's never-ending process of evaporation of water from the oceans and the earth's surface and its return to earth as precipitation

larva
the wingless, often worm-like form of a newly-hatched insect (plural: larvae)

microorganism
a microscopic plant or animal (for example, a bacterium or protozoan)

organism
any living thing (plant or animal)

pH
a measure of the acidity or alkalinity of a solution. A pH of 7 is neutral: higher numbers indicate increasing alkalinity; lower, increasing acidity

plankton
plant and animal organisms, usually microscopic, that occur in vast numbers in ocean water

porosity
being permeable, or having holes or spaces

precipitation
water droplets or ice particles, condensed from water in the atmosphere, which fall tc earth as rain, snow, sleet, hail, dew, etc.

recharge
to replenish ground water by injecting or allowing water to reach the aquifer (ground water reservoir) by percolating through the soil

sample
to take and analyze a specimen to determine characteristics of the whole

species
a fundamental biological classification that groups together organisms which are capable of interbreeding

toxic
harmful or poisonous

turbidity
suspended material in water which affects the water's clarity, or clearness. Measured by water quality technicians in terms of "turbidity units," turbidity is one important measure of how safe water is to drink

typhoid
an acute, highly infectious disease that can be transmitted by contaminated water

water quality
suitability of water for an intended use, such as household, industrial, agricultural, wildlife, etc.

water table
level water stands at in a well

zooplankton
floating, often microscopic, animals

Water Education
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Layperson's Guide to Drinking Water

Prepared by the Water Education Foundation

Contents

The *Layperson's Guide to Drinking Water* is prepared and distributed by the Water Education Foundation as a public information tool. It is part of a series of Layperson's Guides which explore pertinent water issues in an objective, easy-to- understand manner

The Water Education Foundation is a non-profit, non-partisan, tax-exempt organization Its mission is to develop and implement educational programs leading to a broader understanding of water issues and to resolution of water problems

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On the Cover

Water is tested regularly by California water purveyors before being distributed to the public.

Introduction

Next to air, water is the most vital substance for human life. We have to drink water in some form every day. Because it is a necessity, we have come to consider safe drinking water as our right. In the United States we expect to be able to travel from state to state and find good quality drinking water wherever we go.

Most public water officials in the United States believe that public drinking water is the safest thing you can drink. It must meet some of the most stringent standards in the world. Yet many people served by public water systems are buying bottled water and home treatment devices, and some even boil their drinking water.

Why is there so much alarm? One obvious reason is the extensive media attention that some water pollution problems have been getting. Sites of toxic pollution from industrial chemicals have been widely publicized, and when ground water is affected it sometimes is a drinking water source. In the few cases where public water wells have been affected in California, the wells have been abandoned or the water treated or mixed with higher quality water to the extent needed to meet drinking water standards. Because toxic pollution has frightening implications, people also tend to attribute those threats to any level of water quality problems they hear about, even where contaminants are found in very minute traces.

Scientific evidence shows that the fear of cancer from long-term effects of drinking water contaminants is not well founded, despite the alarming things we read in the papers or see on television. The American Cancer Society tells us that over the past 30 years cancer rates have stabilized or declined for all types of cancer except lung cancer. Most drinking water standards for substances believed to be carcinogenic are set at a level considered low enough to be calculated as a 1-in-a-million cancer risk over a 70-year lifespan. (This does not mean that one person in a million is expected to get cancer; it means there is 1-in-a-million chance that anyone will.)

According to the American Cancer Society's identification of major risk factors associated with cancer, only about 2% of the total cancer risk level could be attributable to any of the pollutants identified in water, including man-made organic compounds. High fat, low fiber diets, smoking, and alcohol are identified as by far the major known cancer causes. But people remain seriously concerned about the possibility of even trace amounts of cancer-causing substances in their drinking water. One reason for the concern — and the flurry of standards setting — is that detection technology has improved markedly in recent years, and trace amounts of substances can be found that once went undetected. Many years of research will be necessary to find out if any of these substances pose a scientifically accepted danger in such minute amounts. Another reason is that amendments to the federal Safe Drinking Water Act require limits to be set on many more substances. Research is being done to help decide what the safe limits should be, so we hear more about potential dangers than we did in the past.

There are wide variations in quality among different water supply sources. Californians get their drinking water from Sierra streams, from the Sacramento-San Joaquin Delta, from the Colorado River, and from local sources including ground water wells. The quality of drinking water has recently become a topic of great interest due to the passage of the federal "Safe Drinking Water Act" and state laws including Proposition 65, the "Safe Drinking Water and Toxic Enforcement Act of 1986." Proposition 65 is designed to prevent the discharge of unsafe levels of chemicals known to cause cancer or reproductive harm into actual or potential drinking water sources. Another event bringing focus on water quality issues is the three-year Bay Delta hearing being held by the State Water Resources Control Board. The hearing is to examine all the competing uses of Delta water and consider water quality impacts on the Delta and San Francisco Bay. The end result will include a salinity control plan, pollutant policy document and ultimately a new water rights decision.

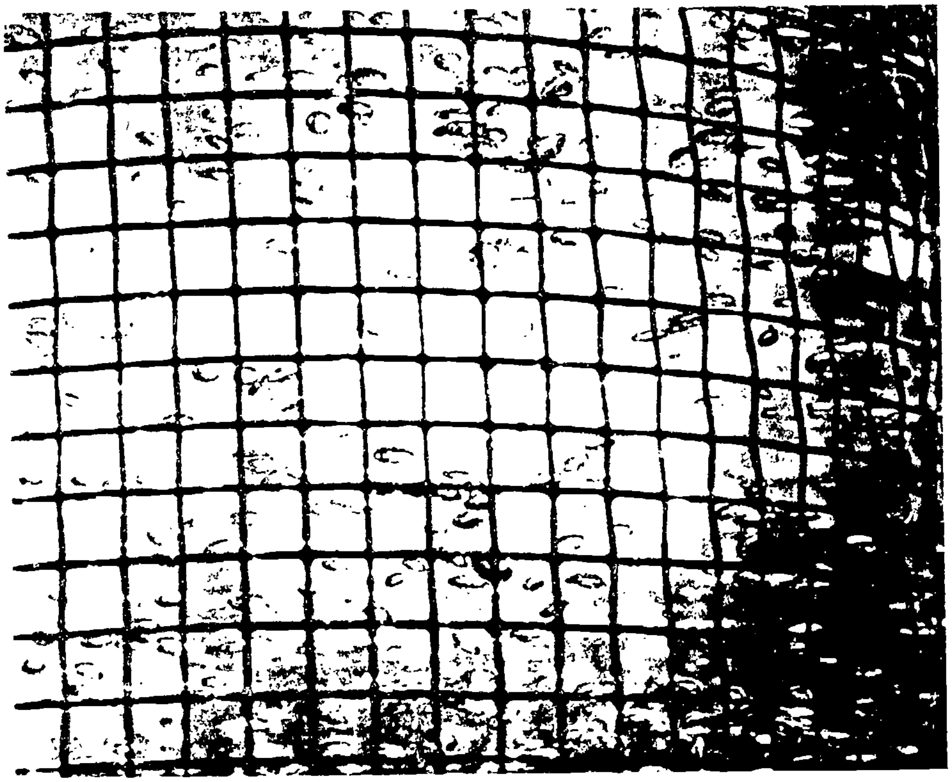
The purpose of this guide is to present the facts and issues about today's drinking water in simple, easy-to-understand language. It explains what some of the major concerns and controversial issues are, what we need to know to resolve them, and describes the kinds of decisions we have to make. For additional information on related topics, consult the **Layperson's Guide to Ground Water.** Other easy-to-understand materials available from the Water Education Foundation include guides to **San Francisco Bay, Delta, Water Conservation, American River, Colorado River,** and **Agricultural Drainage.**

The Body's Need for Water

The body of a normal person weighing about 145 pounds contains about 40 liters (10.5 gallons) of water. At the weight of 8 pounds per gallon, the body's weight is more than half water.

The body loses two to three liters of water each day through kidney functions to remove waste, perspiration to help control temperature, and respiration. The lost water must be replaced for us to maintain good health. Thus, most people should drink about two liters, or six to eight glasses of water or other liquids a day.

In a sense, the human body is itself an aquatic system. The organs function by the circulation of fluids through the body. The chemical processes that build and maintain body tissues and supply energy for activity take place in the body's aqueous environment.



The Toxics Scare

[illegible] react generically to "toxics" in the water as alarming, regardless of the nature of the amount in question. This is in part due to the many frightening terms which are being used in connection with these problems. A drop of gasoline or solvent in a glass of drinking water might be totally unacceptable. One drop of this same substance in a year's supply of drinking water might not be anything to get excited about.

The momentum has developed for ridding our environment of toxics, and the arguments for making rational distinctions and balances between various risks and priorities are often not being heard. People are confused about the dangers and are unwilling to accept any amount of involuntary risk.

EPA has a **trichloroethylene (TCE)** level of 5 parts per billion as the allowable limit in drinking water, while the federal Food and Drug Administration allows decaffeinated instant coffee to contain 25,000 parts per billion. (One part per billion is the equivalent of one drop in a high school swimming pool, or one person in the population of China.) If these substances are really dangerous in such small amounts -- to us or future generations -- we should spend the money to remove them. The problem is, scientists don't know if most of them are dangerous in those amounts or not.

Many experts believe that trace organic compounds in drinking water pose little or no health threat. Some researchers believe that carcinogens have to be over a certain threshold to pose significant risk at all. Others argue that for any known carcinogen in animals, any amount poses a risk and none should be allowed in public water supplies. Regardless of which position is taken, it is important to realize that the costs of achieving zero-contamination are limitless.

In fact, it will never be possible to take out all the contaminants that get into water. Regulations now being proposed will determine how far we will go in removing the contaminants from drinking water and where we will concentrate our efforts.

To guide these decisions, the public needs to be given enough information to determine when the risk is trivial, and when the risk is perhaps greater and may justify a large expenditure. One way to focus on the facts is to stop reacting to the language and learn what the terms mean. Misuse of the word "toxics" could be responsible for much of the fear about our drinking water.

Toxic means poison. No substance can legitimately be described as "toxic" without regard to the amount, (dose or concentration) to which we are exposed. The term might be applied without much argument to cyanide, heroin, nicotine, or strychnine, because their lethal dose for a 150-pound person is only a few drops, but for even these substances there is a threshold level below which no significant harm can be detected or measured. Today, every substance that is known to be poison in any amount is frequently referred to as a "toxic chemical". This terminology tends to obscure the speculative nature of the risks they may pose.

There are different forms of toxicity. Acute toxicity harms (or even kills) organisms by doing short-term or immediate damage. Chronic toxicity harms by causing long-term or cumulative effects, such as the development of cancers or certain vascular system degeneration. Lead, cadmium, some radioactivity, and many of the regulated organics are suspected or known carcinogens.

Many toxicologists believe that there is no clear non-damaging threshold level for these chronic toxic substances. This concern, of course, results in a call for lower permissible levels than would otherwise be appropriate. In any event every toxic material has an exposure level below which it is not prudent or cost-effective to mandate removal. The search for that prudent exposure limit is the crux of our drinking water regulatory dilemma. The inability of scientists to agree on what the safe limits should be is the source of much of the confusion about how serious these problems may be, and the public's desire to eliminate all risk makes agreement even more difficult.

Laws

MAJOR GROUNDWATER PROTECTION LAWS STATE OF CALIFORNIA

Law and Enforcement Agency	Provides for
Porter-Cologne Water Quality Act (1969) SWRCB and nine regional boards	Protection of the quality of surface waters of the state.
(California has primary responsibility for enforcement of federal RCRA and SDWA. Various agencies are involved, primarily Dept. of Health Services, SWRCB and Regional Water Boards)	See federal laws: RCRA—hazardous waste control SDWA—discharge of contaminants to drinking water
Title 22, Calif. Administrative Code, **Domestic Water Quality and Monitoring Regulations** Department of Health Services	Public water suppliers to regularly monitor systems for certain contaminants in drinking water and report results to DOHS. Lists primary and secondary drinking standards. (Constitutes California's equivalent program to EPA SDWA standards.)
Title 23, Chapter 3, Subchapter 15, Calif Administrative Code, **Discharge of Waste to Land** State Water Resources Control Board and 9 regional boards	Regulation of discharges of hazardous, "designated" and solid waste to landfills, waste piles, surface impoundments, and land treatment units for treatment, storage, or disposal. Requires zero discharge and monitoring for hazardous and designated waste. (Constitutes California's RCRA equivalent, with other DOHS regulations.)
State "Superfund" Department of Health Services	$100 million program established in 1981, and funded by taxes collected from waste generators, for cleanup of hazardous sites. Amended and increased in 1984 with passage of bond issue.
Toxic Pits Cleanup Act of 1984 State Water Resources Control Board and 9 regional boards	No discharge of hazardous wastes within ½ mile upgradient of a potential drinking water source by 6/30/88, and closure by 1/1/89 of surface impoundments unless double-lined, provided with leachate collection system, and monitored
Various Underground Tank Control Laws DOHS, SWRCB, local agencies (Local agencies, usually county health, public works, or fire departments are responsible for permitting and monitoring. When groundwater has been impacted the regional boards are usually requested to be the lead agency to enforce cleanup.)	Reporting, inspection, permitting, monitoring, testing, double containment, repair or removal of leaking underground tanks. 1987 amendments extended regulations to certain farm tanks.
Solid Waste Disposal Site Prioritization, Water Code Section 13273 SWRCB and regional boards	SWRCB to test and rank all 1200 solid waste (garbage) disposal sites in the state. 150 sites to be tested each year until all have had solid waste water quality assessment test (SWAT). A SWAT is one-time air quality, groundwater and vadose monitoring to see if hazardous wastes are leaking from the landfill.
Monitoring of Large Public Water Systems AB 1803 (1983) Department of Health Services, SWRCB and regional boards	DOHS to monitor all public water systems for contaminants, regional water boards to review data and identify discharges which have affected the public drinking water wells. (Later amended to include small systems.)

Law and Enforcement Agency	Provides for
Proposition 65. Toxics Initiative. **Safe Drinking Water and Toxic Enforcement Act of 1986** Lead agency Health and Welfare: Advisory Group: secretaries of Business. Transportation. and Housing Agency. Environmental Affairs and Resources agencies and directors of Departments of Food and Agriculture. Industrial Relations. and Health Services.	Governor to publish a list of chemicals "known to the state to cause cancer or reproductive toxicity," to be updated annually March 1. Requires dischargers of any listed chemical to warn any individual who may be exposed Prohibits discharge of any amount of a listed chemical where it might reach potential water supply unless discharger proves there is no significant risk or observable effect Provides for penalties and citizen enforcement actions with filer's sharing of penalties with enforcement agency and superfund.

MAJOR PROTECTION LAWS
FEDERAL

Safe Drinking Water Act (SDWA) 1974 Amendments (1986) U.S. EPA and enforced by State	EPA to set national standards for drinking water quality. Maximum contaminant levels (MCLs) to be set for a wide variety of contaminants to establish maximum allowable concentrations. Local water suppliers to monitor public water supplies to assure that MCLs were not exceeded, and report to consumers if they were; and to achieve compliance.
SDWA Amendments U S EPA and enforced by State	• EPA to set standards (MCLs) for 83 named contaminants within 3 years. • Local water supply systems to monitor for a broad range of contaminants besides those with MCLs. • EPA to require filtration and disinfection of surface supplies not adequately protected and to consider disinfection for ground water supplies. • Grant programs and technical and financial assistance to small systems and states • Strengthened enforcement authority • Grant program for designating sole source aquifers for special protection • Ban on future use of lead pipe and lead solder. • EPA to evaluate monitoring methods for deep well injection waste disposal sites. • Well head protection program
Clean Water Act (Protects ground water indirectly by protecting quality of surface water.) U S. EPA and enforced by State.	EPA to set standards for surface water, require sewage treatment, and limit discharge of industrial and municipal wastewater into surface waters.
Resource Conservation and Recovery Act (RCRA) U S EPA and enforced by states	EPA to develop regulations to track wastes from "cradle to grave" covering generation, storage, transport, treatment, and disposal of hazardous waste. Protects all sources of groundwater from contamination by hazardous waste Also prohibits pollution of surface water and air by hazardous waste sites.
RCRA Amendments	Reauthorization and amendments to increase the number of waste generators subject to regulation and placement of underground storage tanks under EPA regulations.
Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) (known as "Superfund")	Funds and EPA authority to clean up existing hazardous waste sites based on priority of threat to water or other resources Also creates liability provisions for federal and state to seek reimbursement from responsible parties (generators, transporters, or disposers) for cleanup, or to seek a court order requiring those responsible to clean up a site.
Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) **Toxic Substances Control Act (TSCA)** U.S. EPA	EPA to regulate pesticides and toxic substances that may have an adverse effect on the environment, including groundwater and other drinking water sources.

Volatile Organics

Even the word "chemicals" has acquired a frightening connotation, partly because it is so often linked with "toxic" and "dangerous". Every substance in the world is made up of chemical compounds of a few more than a hundred basic elements. We use those same elements to create "man-made chemicals". A piece of firewood has thousands of chemical constituents in each fiber. Water is a chemical compound. So is everything else.

Scientists use these terms in their work so they do not have the same emotional reaction to the words. When we look at what the words mean, they tend to lose some of their power to frighten. One of the basic elements, carbon, is present in every living thing. Chemical compounds containing carbon are called "organic chemicals." Organic chemicals make up most of the foods we eat.

Then there is another term, "**volatile organic chemicals**", or **VOCs**. Volatile, in chemical terms, does not mean explosive; it simply means it evaporates readily at room temperature. Volatile organics can be something unpleasant to breathe, like gasoline fumes, or as sweet as the scent of gardenias or orange blossoms. (The term volatile or even "aromatic", has nothing to do with scent but if you can smell it in the air something has become volatile or it wouldn't reach your nose. There are volatile chemicals that have no perceptible odor.)

Volatile organics can be removed easily from drinking water because they are inclined to evaporate readily. However, it is expensive to remove them from large amounts of ground water because large quantities of water have to be pumped. The most common treatment involves forcing air upward through a tall column of packed materials over which the pumped water trickles downward. The chemicals then volatilize (evaporate) out of the water and into the air.

This is not to say that some chemicals are not harmful. We know some are just from the ones we use in our homes, like ammonia and chlorine bleach. Most of us have learned to be cautious in using these chemicals, and as a society we are learning to be more cautious about them in the environment.

But because we are familiar with household cleaners and solvents, they do not carry the same trepidation for us as chemicals with mysterious names, like **TCE**. Many of the substances that get into drinking water have been identified as carcinogenic or "potentially carcinogenic." When evaluating reports of carcinogens in our water, the things to consider are the amounts in question as well as the basis for their being described as carcinogenic.

Whenever there is a higher than normal incidence of cancer or birth defects in a community something toxic in the water becomes a prime suspect. This is a reasonable place to start looking because water is one of the fundamental things everyone affected has in common. However, the problem could also come from many other sources, such as the air, food, common building materials in the homes, a common work-place, or even substances naturally occurring in the soil.

Many of the regulations now being set to protect the environment are placed far below the exposure levels we have from other sources in everyday living. These regulations are being demanded by the public, and legislators are responding by passing new laws each year. Critics of increasingly strict standards warn that these laws will cause the price of water to skyrocket, and yet accomplish very little, unless efforts are concentrated on eliminating the most serious health threats.

Progress is being made in developing methods to assess risks and to put them into meaningful perspective, however it is still a very primitive field. As scientists with differing viewpoints begin to explain relative risks in understandable terms, the public can begin to make better informed decisions about "how safe is safe enough?" and other similar questions. However, subjective factors will continue to influence public opinion. Like most of our water problems, this one has no easy solution. It does seem clear that better decisions will be likely if we can reduce the influence of panic at the word "toxics".

What Happens from the Source to the Tap?

Water treatment technology is remarkable in cleansing "the universal solvent" from all the potential perils from its source to our tap. Clear mountain springs might be flowing through sulfur, zinc, or arsenic-laden soils. Lakes, rivers, and aquifers can pick up contamination such as nitrates from fertilizers or septic tanks, from acid mine drainage, or naturally occurring minerals. Rivers and streams sometimes carry harmful bacteria from animals and the risk of disease. Storm-caused urban runoff can also carry pollution into rivers and streams.

Pollutants can also enter the water from agricultural drainage and runoff, and from wastewater discharges. Other potential sources of pollution are landfills and other waste disposal sites, where rain water can soak into the ground and leach out harmful substances and carry them into water supplies. In our homes, factories, and buildings corrosive water can dissolve metal in the pipes, such as lead solder, or can be contaminated by accidental cross-connections with nonpotable water sources.

Yet these potential routes of contamination have been explored for decades, and many of these problems have been solved. Though they still have to be guarded against, they are well understood. Water quality professionals have developed methods to detect them, measures to avoid them, and modern treatment techniques to eliminate these harmful effects before the water is delivered to consumers of public water supplies.

Despite concerns about possible contamination of future water sources, existing supplies of public tap water in the U.S. are unquestionably safe to drink. Where public water is available, it is rarely necessary for people to spend money to buy bottled water or install home treatment devices.

Current and proposed EPA regulations on the quality of drinking water in the U.S. ensures consistent, good quality drinking water throughout the country. Researchers continue to study the long-term effects of contaminants that may occur in the water supply.

What The Letters Mean

MCL Maximum contaminant level set by EPA for a regulated substance in drinking water. The MCL must be set as close to the Goal (MCLG) as feasible, using best treatment available considering cost.

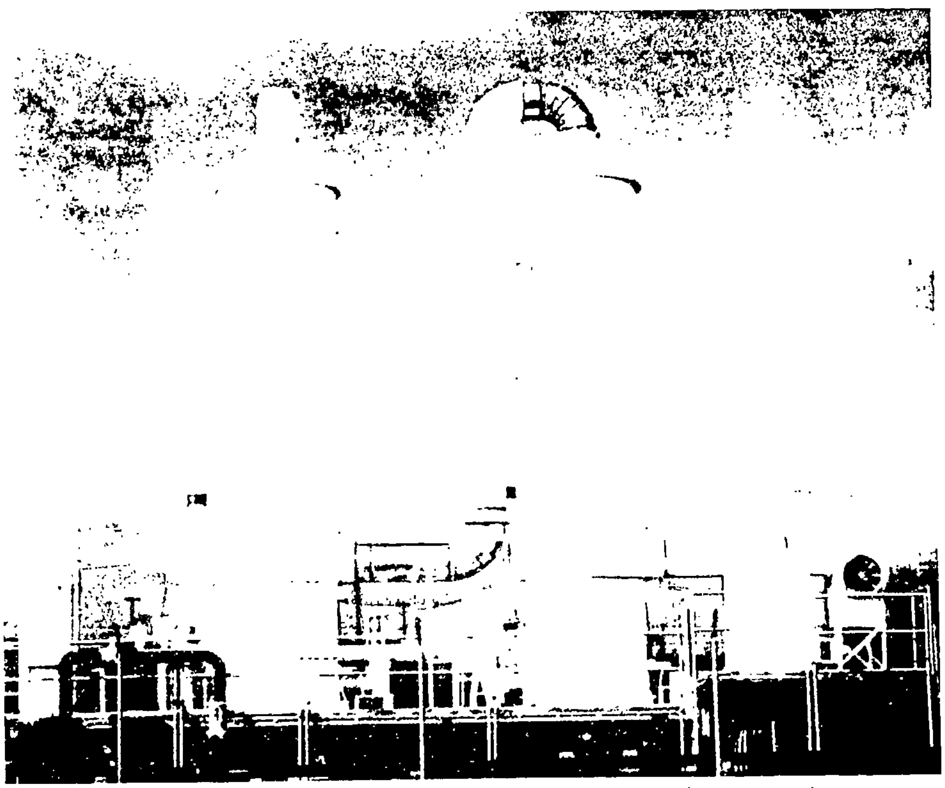
MCLG Maximum contaminant level goal set by EPA for each regulated substance in drinking water. The goal is to be set at a level at which no known or anticipated human health effects will occur allowing an adequate margin of safety.

TCE Trichloroethylene—A VOC used as a degreaser or solvent (commonly used in industry, dry cleaning, and household carpet cleaners).

THMs Trihalomethanes—Any of several synthetic organic compounds formed when chlorine combines with organic materials in water. One of the most common THMs is chloroform.

THMFP Trihalomethane formation potential—Depends on amount of organic material present in water to combine with chlorine to form THMs.

VOC Volatile organic compound—A chemical compound which evaporates readily and contains carbon. Regulated VOCs include both chlorinated organic compounds, such as TCE, and aromatic organic compounds, such as benzene. VOCs are used as solvents and degreasers, and are present in fuels such as gasoline.



*Air stripping systems can remove **VOC's** from millions of gallons of water per day.*

What About Trace Organics?

The biggest challenge today is in dealing with newly discovered problems that may or may not pose real threats to public health. Because of our ability to detect minute traces of substances in ground water, we have learned that ground water is not contaminant-free, as we once believed. Testing of ground water throughout the country has uncovered the presence of industrial and agricultural chemicals, gasoline from leaking tanks, and other substances that have percolated into ground water supplies.

In the past many people did not believe that dumping of these chemicals would pose significant risk. Contamination of ground water can be a serious problem if it is extensive, because the contaminant generally travels slowly and unobserved until it reaches a water supply well and eventually is detected. By then it has dispersed in the ground water and is more difficult to remove.

Another disquieting discovery in recent years was that drinking water can acquire new chemicals even from the treatment techniques used to disinfect it. **Trihalomethanes**, or **THMs** are formed as chlorine is added and combines with naturally occurring organic material in most surface waters. Because **THMs**, such as chloroform, are suspected human carcinogens, some people fear that they may be harmful over many years of exposure, even in the trace amounts that they occur. Water utilities are taking various actions to reduce **THMs** while continuing to assure adequate disinfection.

On a relative scale, the potential danger posed by trace organics formed in water treatment is insignificant, considering that the use of disinfectant (mainly chlorine) has virtually eliminated life-threatening microbiological epidemics from U.S. water supplies for over 70 years and has given us longer life expectancy. In that context, our concern about traces of substances that might possibly cause a low level cancer increase if ingested over a lifetime might appear out of balance with other public health concerns. Yet it is because we continuously examine new information and take a fresh look at past assumptions that we continue to improve th[e s]afety and reliability of our drinking wa[ter].

Water Treatment

Water Treatment

The glass of water you are about to drink has a long and glorious past. It may once have coursed down the Ganges, or splashed into Julius Caesar's bathing pool. The water we use now is the same supply the human race started with. The total amount in the global cycle remains essentially constant, though its distribution is continually changing. Its quality is renewed through the hydrologic cycle. In the cycle water evaporates from rivers, lakes, and streams and goes into the air as water vapor, where it returns in the form of precipitation: rain, snow, sleet or hail.

Surprisingly though, good quality drinking water does not just fall from the sky. A great deal of trouble and expense—and advanced technology—goes into making our public drinking water supplies safe to drink.

Rain water has already acquired impurities even as the water molecules collected into drops. Particles of dust, smoke and salts in the atmosphere combine with the water. Airborne gases, such as carbon dioxide, sulfur dioxide and nitrogen oxide might also combine with the droplets to form weak acid solutions. When the drops reach the earth, they break down rocks, dissolving minerals in the rocks and soil. The water, which was briefly composed only of two atoms of hydrogen and one atom of oxygen, now has minerals such as sodium, chloride, calcium, iron, and magnesium both dissolved and suspended in it.

Water is called "the universal solvent" because in all its forms: ice, liquid or vapor, it is affected chemically by the materials it comes in contact with. Besides its chemical alterations from contact with earth and sky, water also has biological aspects. Organisms, plants, and animals live in water, and its physical and chemical properties affect its suitability for their habitation. Conversely, their habitation of water affects its suitability for us to drink. Algae can make water smelly and unappealing, but a more insidious problem is the disease-causing organisms which cannot be tasted or seen, from organisms in the fecal matter of animals, such as muskrats and beavers, and land animals including humans.

A century ago the biggest concern of public water suppliers was controlling water-borne disease. Before disinfection became a common practice, widespread outbreaks of cholera and typhoid were frequent throughout the U.S. These diseases are still common in less developed countries, but disappeared in the U.S. when chlorine became widely used more than 70 years ago.

Good Drinking Water

Water used for drinking and domestic use should taste good and be free of unpleasant odors. It should be free of disease causing organisms and not contain any substances at levels that could be harmful or toxic. It should look clear and not be slimy or discolored. Its pH balance should be in a neutral range so as not to be too acidic or alkaline. It should not be corrosive to pipes or plumbing.

Turbidity, or clarity, of water was once considered chiefly an aesthetic consideration, but it is now a primary regulation for public drinking water. This importance is placed on turbidity because particles suspended in water can shield disease organisms and allow them to escape the effects of disinfection.

Today our drinking water supplies are being increasingly regulated for every condition known or even suspected, to affect human health. A public water supplier operating a treatment system today has methods to control nearly all the properties of the water: hardness, acidity and alkalinity, color, turbidity, taste and odor, as well as the biological and organic chemical characteristics. Large water suppliers maintain their own laboratories equipped to test water for all these properties and constituents. Water agencies in smaller communities use commercial laboratories.

Despite all the care and treatment we give our drinking water, it is an ever-changing, ever-growing task to assure its safety. Like water, which is never static, the rest of the environment is continually changing and our knowledge of it increases with each advancement in the environmental and health sciences. Most public surface water supplies receive full conventional treatment. All public supplies probably will soon unless they can pass stringent standards, because of proposed new EPA surface water and ground water treatment requirements.

Conventional Treatment

Coagulation/Flocculation

Coagulants such as aluminum sulfate, ferric chloride or organic polymers are rapidly mixed into the water. This alters the electrical charges surrounding the suspended particles to make them attract and coagulate, or clump together, into larger particles known as floc. In flocculation, the water is gently agitated so the floc particles will collide with each other and entrap other suspended particles forming still heavier particles.

Sedimentation

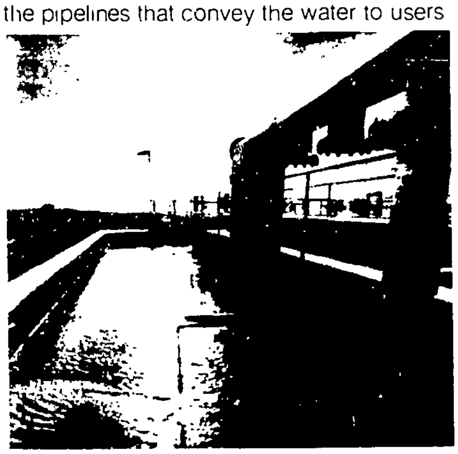
The flocculated water moves slowly through a basin or tank to allow the heavy floc particles to be removed by settling to the bottom. Coagulation/flocculation/sedimentation steps reduce turbidity by removing many of the particles that cause water to appear cloudy.

Filtration

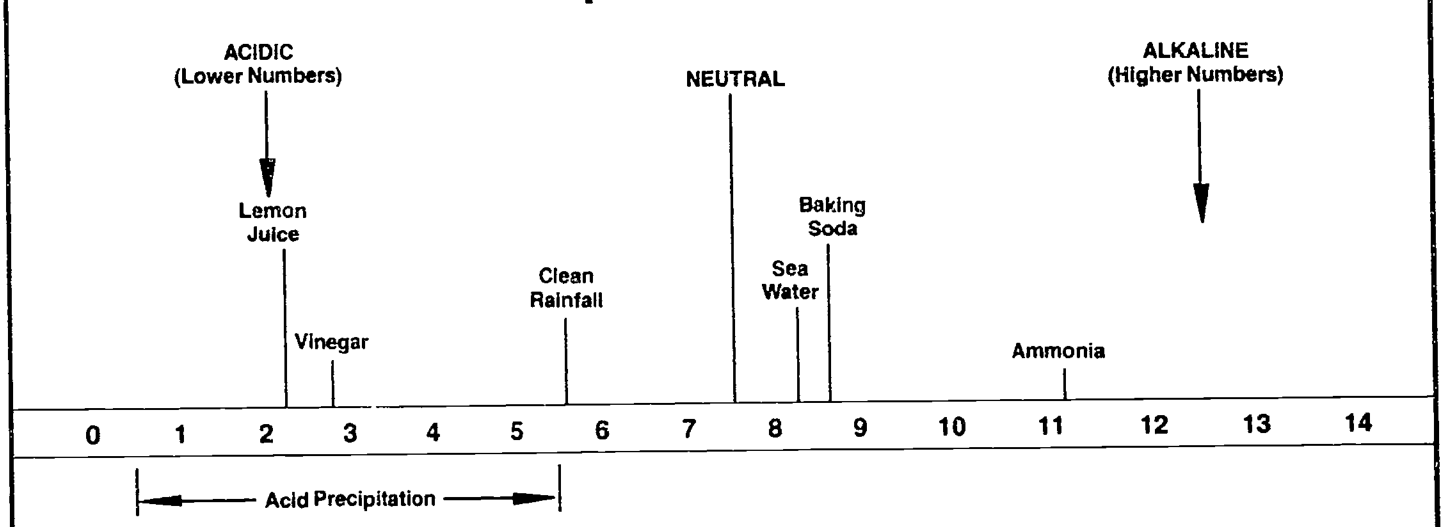
Water is passed through filter media made of sand, coal particles or similar materials to remove small, light particles that do not settle. This process further reduces turbidity and results in water that is crystal clear. Filters are backwashed frequently to remove accumulated materials.

Disinfection

Chlorine, chloramines, ozone, or another type of disinfectant is added to destroy potentially harmful bacteria, viruses, and other organisms. Enough chlorine is added to leave a residual amount of chlorine in the water, to continue to kill any pathogens in the pipelines that convey the water to users.



What pH Values Mean*



*Each number represents a tenfold increase or decrease in acidity.

Other Processes

Aeration

Aeration, the mixture of air with water, is sometimes done if undesirable amounts of iron and manganese are present. they are held in solution in water only in the absence of oxygen. Aeration also removes gases dissolved in the water. Aeration is done primarily to improve the aesthetics of water: color, taste and odor.

Corrosion Control

Other chemicals may be added to water during the course of treatment for specific purposes. Caustic soda or lime may be added to control the corrosiveness of water by adjusting the water's pH. Sometimes complexes of phosphate or silicate are used for this purpose.

Fluoridation

In some systems, fluoride is added to help reduce tooth decay in children. Fluoride occurs naturally in some water supplies, and the amount which can be in drinking water is regulated by EPA.

Disinfection: Is Chlorine Good or Bad?

The use of chlorine for disinfection is an example of the choices society has to face when there is a risk/risk situation and a decision must be made about which risk outweighs the other. The known risks from inadequate disinfection are far greater than potential risks from traces of organic compounds.

Since 1914, chlorine has been the preferred disinfectant in most United States public water systems. Although there are other methods of disinfection, chlorine has been considered the most reliable for controlling water-borne disease. It is relatively easy to use, inexpensive, and when it is added to water it remains, continuing to kill bacteria in the distribution system.

In the late 1960's and early 1970's, scientists began to be concerned about newly-discovered compounds that are formed when chlorine combines with naturally occurring organic materials, such as humic or fulvic acids from soils or decaying vegetation. These synthetic organic compounds, the most common of which is **trihalomethanes**, or **THMs**, were first discovered when new laboratory equipment was developed with the capability of detecting chemicals in amounts as small as one part per billion. **THMs** were not known to be harmful in the minute amounts detected, but no one was sure what their long-term effects might be. When they were found to be carcinogenic to test animals (and suspected human carcinogens), disinfection by-products became the subjects of intense research to define their harmful effects.

With the discovery of **THMs**, chlorination has been called into question. Most water agencies in the U.S. use chlorination as the primary disinfectant. There are other methods of disinfection which do not form **THMs**, or form fewer **THMs**, but the alternatives are not equally effective for every system. Also, the other methods sometimes have problems of their own.

Disinfection

Disinfection Treatment Alternatives

In 1979, EPA set a maximum contaminant level (**MCL**) for **THMs** at 100 parts per billion (or 0.10 mg/l). Some agencies were not able to meet this standard using chlorine, and chose to use other methods of disinfection. In 1985, the Metropolitan Water District of Southern California (MWD) began to use a chlorine-ammonia combination, called chloramines, which greatly reduces the formation of **THMs**. MWD first conducted pilot studies to test its effectiveness, and determined that disinfection with chloramines could be as effective as chlorine by extending the contact time and using chlorine in the distribution system. Chloramines have been used by other major utilities in the U.S. for many years and this disinfection method is gaining in popularity.

Ozonation, a disinfection process used widely in Europe, does not form **THMs**. It has been used less in the U.S. primarily because of cost. Ozone is effective for controlling color, taste and odor. Its major public health disadvantage is that ozone does not remain in the water to disinfect throughout the water distribution system. Therefore, chlorine or another disinfectant must be used also, although less would be needed than if chlorine alone were used. There is some **THM** formation but less than with disinfection limited to chlorine.

Some agencies use ozone to meet requirements unrelated to control of **THMs**. In 1987 the Los Angeles Department of Water and Power began using ozone for disinfection in its new water filtration plant treating its Los Angeles Aqueduct supply. Ozone was selected primarily for its effectiveness in reducing turbidity, since the Department was well below allowable **THM** limits, but the use of ozone and other factors have further reduced **THMs** in the water. The efficiency of the plant was increased and fewer coagulant chemicals are used with the ozone process. The Los Angeles Department of Water and Power continues to use chlorine for disinfection in its distribution system.

Ultraviolet and ionizing radiation are other disinfection methods that do not produce **THMs**. These pose some concerns of their own, and may have unknown side effects. Chlorine dioxide is another alternative that produces few **THMs**. However, it has produced harmful effects on the blood in tests with animals and may produce other inorganic and organic by-products.

Studies are being done to investigate the potential carcinogenic or mutagenic effects of all disinfection methods. Because of less frequent use, there are less data on the potential effects of chloramines, ozone, or other methods besides chlorine, and there is some indication that there may be problems with them equal to the concern with **THMs**.

Obviously, the problem is more complicated than just picking another disinfection method. They are not all equally feasible for every system. The choice depends on what is likely to be in the water, as well as holding time in distribution lines. Some people may be more sensitive to the effects of one disinfectant than another. Many experts are in favor of using chlorine simply because it has been effectively used for more than seventy years with relatively little evidence of serious problems.

THM Control

The EPA maximum contaminant level for **THMs** is 100 parts per billion.

According to a study funded by the American Water Works Association, published in 1984, the existing regulation resulted in a 40 to 50 percent reduction in average **THM** levels in the U.S., at a cost of between $31 million and $102 million. The next increment of reduction, if the standard is reduced to 50 ppb or lower, will cost billions and result in the inability of many utilities to comply, the study concluded.

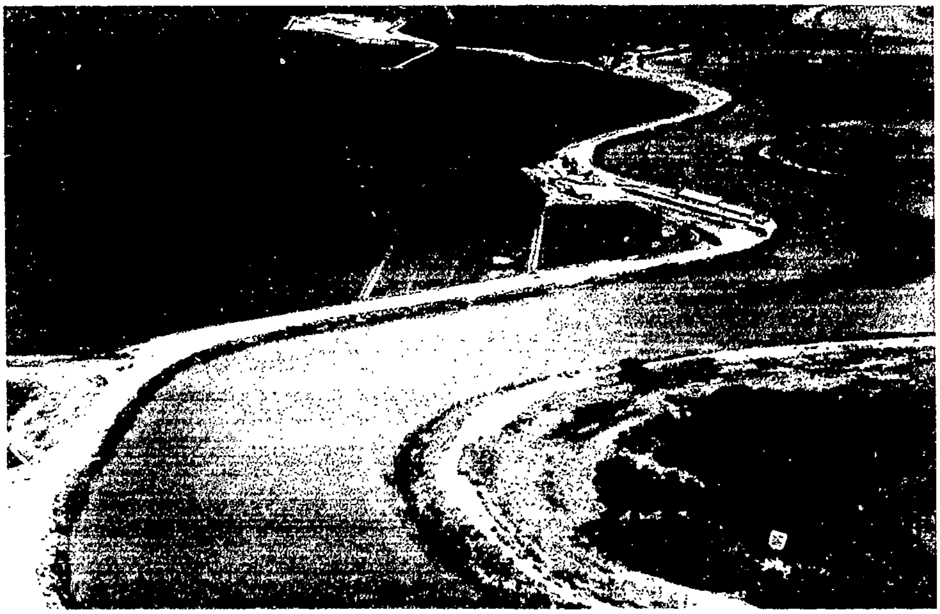
On the basis of the information available now, an EPA source says he would hesitate to say that chlorination should be avoided. The health effects of **THMs** are still debatable, and other treatment may have similar effects.

Even if technical experts favor a standard that would leave the options open for water suppliers to select the optimal disinfection strategy for their systems to get the best public health protection, EPA policy may dictate otherwise. Chloroform, the most common **THM**, is classified as a probable human carcinogen, and therefore requires the maximum contaminant level goal **(MCLG)** to be set at zero. By law, the **MCL** must be as close to the goal as is feasible. If the **THM** standard is set even lower, many systems will be unable to meet it with chlorine and will have to use other types of disinfection.

Reducing THMs At The Source

Some water sources have more organic materials than others, and thus have greater potential for **THM** formation when chlorine is added. The Sacramento-San Joaquin Delta has been found to have high levels of these **THM** "precursors", and consequently a high trihalomethane formation potential (**THMFP**). If these organics could be prevented from entering the water, the formation of **THMs** could be significantly reduced; however it is unlikely that a major **THMFP** reduction can be achieved in water passing through the Delta. The chlorine/**THM** reactions are enhanced by bromides from sea water which enters the Delta from the Pacific Ocean. Agricultural drainage and the San Joaquin River also contain bromides, so there are other sources besides the ocean. The primary source of organic **THM** precursors in Delta waters is from naturally occurring organic substances which are dissolved from Delta peat soils and soils in the watershed tributaries. Further studies are being done to identify the major sources of **THM** forming materials in Delta water supplies.

Forty percent of the state's surface water comes from the Delta, and the Delta supplies drinking water for millions of Californians. If it is not feasible to reduce the **THMFP** there, agencies using chlorine to disinfect Delta water will have to rely on treatment for precursor or **THM** removal or seek alternative points of intake not so severely affected by Delta conditions.



The Delta waters have high levels of THM "precursors."

THM Removal By Treatment

If chlorine is considered to be the best method of disinfection by a water supplier, **THM** levels can be reduced before the water is delivered to the consumer. although this is an expensive undertaking. The feasibility of removal through air stripping or filtration with granular activated carbon (GAC) is being studied by EPA and water suppliers.

Good **THM** control, along with disinfection and reduction of many other organic constituents is being obtained in pilot plants using "advanced oxidation processes" (AOP's). These processes use combinations of ozone, hydrogen peroxide, and UV light to produce hydroxyl radicals, one of the most powerful oxidizing agents that can exist in water. Researchers at UCLA and MWD, with some sponsorship from the American Water Works Association Research Foundation have recently done pioneering work on use of AOP's for large-scale water treatment. They use the term "Peroxone" for treatment with peroxide and ozone. They find excellent reductions of **THM's** at a fraction of the cost of treatment by GAC filtration.

Because of costs and uncertain benefits, municipal water districts have been reluctant to install **THM** removal systems, or other non-required safeguards. However, large water suppliers are beginning to take another look at providing added water quality assurance to their customers because so many customers are investing in home treatment devices and bottled water. The fact that so many people are willing to pay higher costs for water, hoping to get better quality or taste, has caused many water purveyors to believe that consumers will support additional improvements to be better satisfied with their municipal water service.

Although individual water users can buy GAC filter systems, they lack the ability to determine if the filtration system is working properly. Unless filters are changed regularly, such a system could add contaminants instead of removing them. If the supplier furnishes treatment for all users, the overall cost is lower and there is assurance that the system will be maintained routinely by trained personnel.

What You Need to Know

Should You Have Your Water Tested?

If you get your water from a private well, experts say you should have your water tested at least once a year for bacteria. This test will cost about $12 at most water quality laboratories. Shallow wells along rivers and wells built without proper sanitary seals are especially susceptible to bacterial contamination from surface water entry.

If you are concerned about "toxic substances", the tests will cost much more. Testing for minerals can cost from $130 to $200. Testing for organic "priority pollutants" may cost an additional $200-$300. Testing water for everyth ng that might conceivably be in it req s more extensive tests that can cos everal thousand dollars per sample. Fortunately, it is usually not necessary to check for the full range of pollutants. Chances are other wells in your area have been tested, and your county health department is probably familiar with the soil composition and aware of metals or other possible contaminants of concern in your vicinity. County and state health departments keep records on well trouble spots, and can most likely tell you whether any substances of concern have been found in wells nearby.

With EPA funding assistance, the Santa Clara Valley Water District in San Jose published a booklet "A Guide for the Private Well Owner", to answer questions about well contamination. Water Districts in other areas may have similar publications.

If you receive water from a public water system, you can usually get the information you need without having to go to the expense of having it tested yourself. Public water systems must have surface water supplies tested at least once a year, and wells tested every three years. Most agencies, especially larger ones, test the water much more frequently. If you receive a monthly bill for water, the agency that bills you can probably tell you what the water has been tested for, how often, and what the results were. California state law requires all public water agencies to provide the results of their routine testing to consumers upon request.

If you cannot find out who your water supplier is, call the health department in your county. Records of testing of public water supplies are sent to county and state health departments.

If you notice an unusual color, taste, or odor in your tap water, you should report it to your local water agency. The agency can probably explain to you what the cause is and what is being done about it, as well as any steps you should take to be sure the water is safe to drink. If the problem you describe is a potential health problem and they are not aware of it, they will most likely test the water. If you choose to have your water tested for any reason, you should use a laboratory that is certified by the state to conduct the type of analysis you desire.

Should You Boil Your Water?

If you have a private well and suspect bacterial contamination, boiling your water for 15 minutes will kill all disease-causing organisms. If you receive your water from a public supplier, there is frequent testing for bacteria and you would probably be wasting energy unnecessarily.

Exceptions would be when the integrity of the supply is in question (for example, after an earthquake), or if you experier break in your water mainline, or t pe between the house and the street where bacteria could enter the distribution pipes in your house. Most public water suppliers test water as it leaves the treatment plant and at the most remote points in the line, to be sure their entire distribution system is bacteria-free.

Another potential trouble spot is at the very end of a waterline if connections are few and there is not enough use to keep disinfected water flowing in the line (most are looped to avoid this problem). Your water supplier will alert you if a disaster or emergency requires that you boil your water.

Boiling the water will also remove volatile organics, including **THMs** formed in reaction with chlorine. They will be released into the air in your kitchen, and be dissipated into a large volume of air so the amount you actually breathe would be small. Metals dissolved in the water and certain compounds, such as nitrate, are not removed by boiling. In fact, as you boil the water and some of it evaporates, these substances become more concentrated.

Bottled Water or a Home Treatment Device?

If your water is from a public water supplier, there is no reason to look for another source of drinking water unless you don't like its taste. In California both public and bottled water supplies must meet the same state and federal drinking water safety standards. However, mineral water is regulated as a food and does not have to meet drinking water standards. Bottled water could be from the same source as your public water supply, although most bottled water has been put through additional filtration. The amount and type of minerals in bottled water depend on its source and the type of treatment it receives.

The same questions should be asked about bottled water as about public water supplies. You need to know the quality of its source, and what its treatment has been.

Bottled water suppliers in California supported state legislation that increased their performance standards over public supplies in three areas: THM's, lead and volatile organic compounds. However, many water utilities already meet strict standards in these areas.

A home treatment device is unnecessary if you get water from a public supplier. If some individual taste preference or other concern makes one desirable, it is important to be sure the system is serviced regularly and will serve the intended purpose. Bacterial contamination is a risk from dirty filters in home systems. Filtration systems in public supplies are routinely serviced and maintained.

If you get your water from a private well or private water system and you are concerned about its quality, you might want to get a Point of Entry (POE) device to treat all the water that enters your home. The other major type is a Point of Use (POU) filter, which treats the water only at one faucet. Within these two categories, there is a wide variety of treatment units, each for different purposes. Before buying a treatment device, it is important the device be appropriate for your needs. The Pacific Water Quality Association in Huntington Beach, California is a nonprofit trade organization for the home treatment device industry you can contact. Recent California laws require state certification of home treatment devices and truth in marketing to protect consumers from false claims.

Lead in Drinking Water

One of today's concerns that all the experts seem to agree on is that lead is harmful, whether it is ingested in water or inhaled in the air. Lead accumulates in the body, and too much can cause serious damage to the brain, kidneys, nervous system and red blood cells. Infants, unborn children, and young children are especially vulnerable to lead poisoning because they can receive more lead per body weight than adults. Infants on formula have the greatest exposure from lead in water because it is such a big part of their diet.

In recent years federal controls on lead in gasoline, paint, and "tin" cans have greatly reduced the overall exposure people have to lead. The amount in drinking water has therefore gone from a relatively minor contributor to one of the significant remaining sources.

Lead in water supplies is rarely due to the presence of the metal in the water source. If lead occurs naturally in the water, it is removable from public supplies through treatment processes. In the cases where lead is above safe levels at the tap, plumbing materials such as old lead pipes or lead solder in copper pipes in the home are almost always the source of the lead contamination.

Both state and federal laws were recently passed prohibiting the use of lead pipes and lead solder. These laws, resulting in changes in building codes, will protect people in newly constructed homes and apartments from lead in their drinking water.

The amount of lead dissolved from pipes or solder depends on the aggressiveness of the water (unless treated, soft and/or acidic water is more corrosive), the length of contact time between the water and the pipes, and the age of the plumbing. Older plumbing may have developed a protective coating, especially where there is hard water.

Concern for the effects of lead on children led the EPA in 1991 to direct virtually every water supplier in the nation to test tap water for lead. The new rules reduce the old standard of 50 parts of lead per billion parts of water to a two-phase standard of 15 parts per billion at the tap and an average of 5 parts per billion throughout the system.

Other Concerns

What Can You Do About Lead in Plumbing?

Generally, most homes older than five years have developed a protective coating on pipes and there is little risk of elevated levels in older homes.

Water suppliers can treat public supplies to make the water less corrosive where lead is a known problem and replace any old water mains and service connections containing lead.

Families can have the water from their tap tested for lead. This may cost from $20 to $80 per sample at a laboratory certified for drinking water testing. The test should include a "first draw" sample and a "fully flushed" sample. (The first-draw sample will have the highest level of lead, while the fully-flushed sample, taken after running the water for 5 to 30 seconds, will indicate the effectiveness of flushing the tap before using the water.) Most laboratories will furnish sample containers and instructions on how to draw your own tap water samples.

For more information, contact your local water supplier or county or state health department. These agencies can also help you find laboratories certified by EPA or your state as qualified to analyze drinking water samples for lead. You may find a qualified testing laboratory under "Laboratories" in the yellow pages.

What To Do If You Find High Lead Levels

In the rare incidences where you do have a high lead level in your water, follow these precautions: Never cook or drink water from the hot water tap. Hot water dissolves more lead more quickly than cold water

Always use water from the cold tap to make baby formula. Boiling the water will kill disease-causing bacteria, but does not remove lead. If you have been instructed to boil the water, you still must begin with cold water because hot water will have more lead dissolved in it. Never drink or cook with water that has been in contact with your home's plumbing for more than six hours, such as overnight or during your work day. Before using water for drinking or cooking run the water until you can feel it get cooler to "flush" the cold water faucet.

If you own a well or private water source, you can treat the water to make it less corrosive. Corrosion control devices for individual households include calcite filters These should be installed in the line between the water source and any lead service connections or lead-soldered pipes

Asbestos In Drinking Water

Asbestos is a fire-resistant fiber found in the mineral serpentine, a greenish mineral so common in California it has been designated as the state rock. Because of the widespread occurrence of serpentine asbestos is common in some of California's waters. Serpentine is common in the Sacramento Valley, but does not occur in the Eastern Sierra

There is no conclusive evidence that drinking water containing asbestos is harmful. Regulation of asbestos began when it was learned that workers exposed to asbestos through inhalation showed a marked increase in the incidence of lung cancer, as well as gastrointestinal tract cancer.

Because of the hazards of breathing asbestos fibers, in 1986 EPA proposed to ban the use of asbestos roofing and flooring felts, vinyl asbestos floor tile, asbestos cement pipe and fittings, and asbestos clothing, and to phase out all other uses within ten years. Although the ban would not affect asbestos already in place, a specific federal law was passed requiring that schools protect children and employees from asbestos hazards.

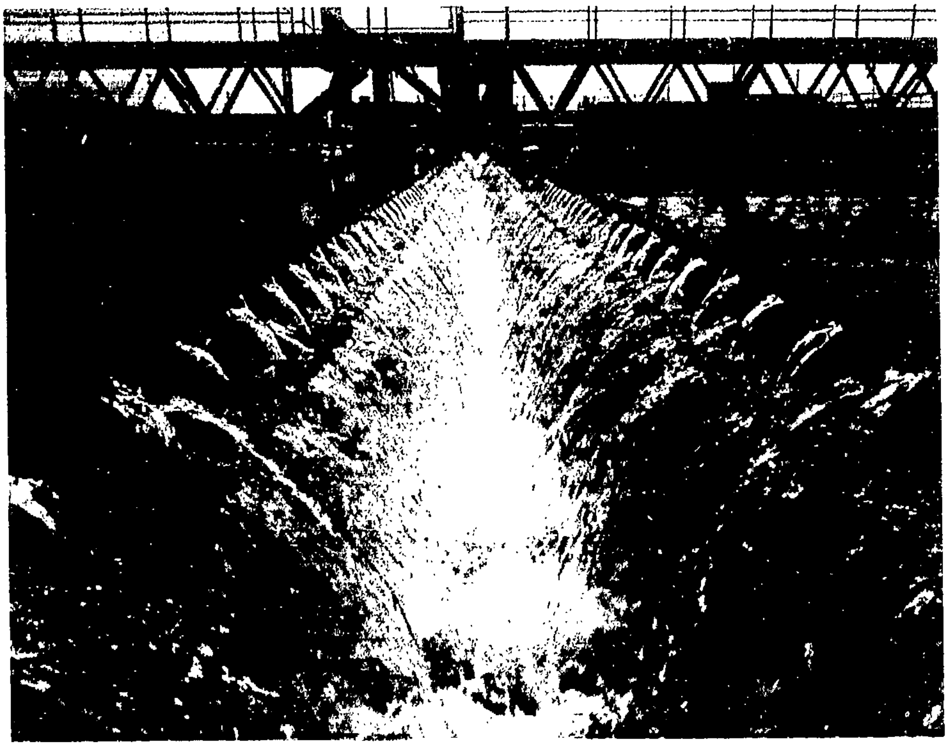
While the ban has not become final regarding asbestos cement (A-C) pipe, regulations for cutting or disposing of the pipe have already affected the water industry and suppliers are looking at alternatives, such as polyvinyl chloride (PVC) for use in water systems A-C pipe has been used in transmission and distribution of water pipelines nationally for over fifty years. Concern about possible health effects of ingesting asbestos fibers—led EPA to set a proposed **MCL** of 7.1 million long fibers per liter.

Conventional treatment includes coagulation and filtration, which can remove asbestos, and these techniques are used in most major public systems using surface water.

Water-borne Diseases

The clear, cold water of a mountain stream looks appealing, but it is not necessarily safe to drink Wilderness waters often harbor microscopic parasites that enter the stream through fecal contamination from animals, such as muskrats, beavers, and larger animals. One such water-borne protozoan is known as **Giardia lamblia**, and is a common problem in California's Sierra waters. Giardiasis, the infection caused by Giardia causes nausea, cramps and diarrhea in humans EPA is currently setting standards to control Giardia. **Legionella** and other enteric viruses A similar disease **Cryptosporidiosis**, was a known cause of diarrhea in many animal species but only recently has been recognized as a cause of intestinal disorders in humans It is now suspected as the cause of mild gastroenteritis worldwide, including cases of traveler's diarrhea, and one of the causes of acute childhood diarrhea in developing countries It is also frequently reported to occur in animal handlers Infection with this organism is more common than previously suspected. Like Giardia cysts, Cryptosporidium cysts appear to be highly resistant to the usual levels of chlorination of potable water supplies, and may have different filtration requirements because they are much smaller. Boiling the water can protect well owners and backpackers from both these diseases Ozone may be more effective against these organisms than chlorine, but most experts believe a combination of treatment techniques is needed to kill or remove them.

Small communities cannot always afford elaborate treatment systems and some rely on a single method to meet health requirements. A combination of several methods is more effective for various kinds of organisms and metropolitan systems usually have this kind of protection The concept of fecal contamination is commonly misunderstood. When people hear this explanation for an outbreak of disease, they are often outraged and envision their water supplies polluted with animal feces. Bacteria can survive in microscopic particles of fecal matter. It is these particles, that can only be seen by great magnification, that only rarely survive filtration and end up in water supplies



Nitrates

What About Nitrates? One of the leading environmental problems worldwide is nitrogen pollution of ground water. The primary concern is that valuable ground water sources will be lost to future generations because human activity is causing the buildup of nitrates above what the environment can assimilate. (Some natural denitrification takes place in soil and ground water.) High nitrate levels are not allowed in public drinking water supplies, and are of greatest concern in private wells (which tend to be less protected against runoff and shallow groundwater).

High levels of nitrates and nitrites in water are suspected of causing cancer, but are the known cause of Methaemoglobinaemia, or Blue Baby Syndrome. This is a sometimes fatal disease of infants (under three months) caused when nitrate reacts with the blood, making it unable to transport oxygen and causing suffocation.

Nitrates in the environment come from the application of nitrogen fertilizers, livestock, and sources such as sewage treatment plant discharges and septic tank leach

Nitrogen is essential to plants, which assimilate it in the form of ammonia and nitrate to produce proteins. Plants also receive nitrogen from animal and human wastes and from the atmosphere. Plant growth is enhanced and speeded up by the addition of chemical fertilizers which supply other nutrients and supplement nitrates. Intensive farming has increased the amounts of chemical fertilizers applied to the soil. California's farm organizations are concerned about this problem and are working with agricultural advisors and farmers to help them achieve the proper balance of nitrogen for their crops without causing ground water problems. Wellhead protection programs can also help reduce the danger of future agricultural practices endangering water supplies.

Many environmental groups favor banning chemical fertilizers altogether, pointing out that even if all applications could be stopped now, the effects of past use of these fertilizers would still be felt 20 years from now because of the slow movement of ground water. Agricultural experts say that food shortages would result if chemical fertilizers could not be used.

EPA has set 10 parts per billion as its maximum contaminant level **(MCL)** for nitrates in drinking water.

Radioactive Materials In Water

EPA is now developing standards for radionuclides in water, but the biggest concern seems to be about breathing their decay products, not drinking them. Radionuclides are radioactive forms of basic elements, and they can exist in many different states.

Radon is the one we seem to be hearing the most about. Radon gas begins as the element uranium, which decays to radium, then to radon gas. Radon is a colorless, odorless, and apparently harmless gas, but its decay products, called radon "daughters", attach themselves to airborne particles that can be inhaled into the lungs. Breathing high levels of these radon decay products is believed to be one of the major causes of lung cancer.

Radon gas can seep into houses from underlying geological formation or from rock foundation materials, but it is also sometimes in ground water and migrates to the rest of the home environment when the water is agitated by running from the tap or shower. It is the overall level in the home that determines whether there is enough of the gas to be dangerous to health. Radon levels can be reduced by simple measures to improve ventilation in the home, like venting basements or even merely opening windows or doors to promote more exchange with the outside air. Tightly insulated homes are the most likely to pose a risk from high radon levels.

Elevated levels of radon have been found primarily in the eastern U.S., but also in some Western states. The California Department of Health Services says that testing so far in California has found only a few water utilities with fairly high radon levels. One state source noted the highest levels found in the state were in foothill and mountain areas east of Fresno and in San Bernardino County using ground water from granite rock formations. Radon is unlikely to be present in surface water supplies because in transport the water has been agitated and has probably lost any radon it may have had.

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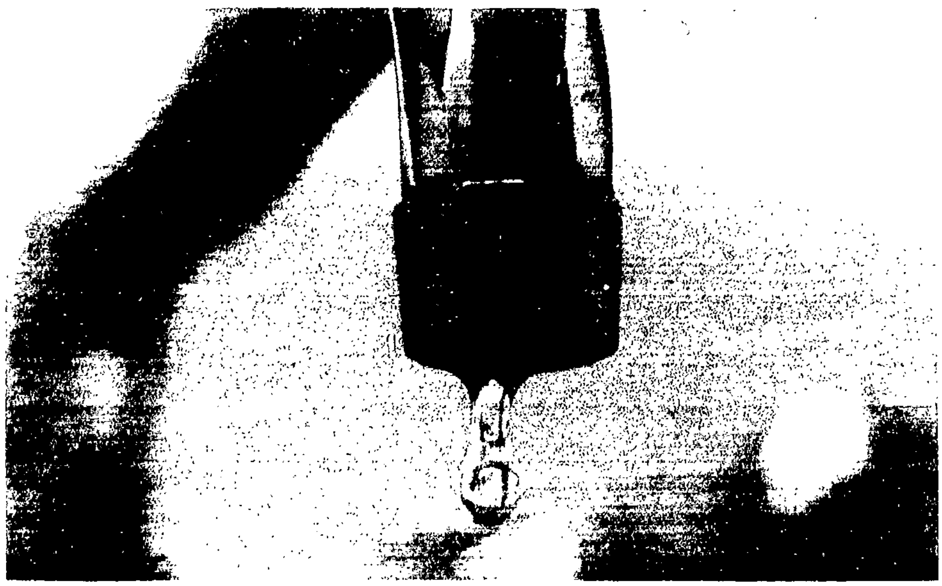
Conclusion

In this guide we have discussed most of the health risks that are possible if drinking water becomes contaminated. The threats from water-borne diseases are easy to assess because we know from human experience the illnesses they can cause, and how serious they can be. Toxicologists can calculate dose-response curves for systemic effects of toxins, such as lead. For many kinds of contaminants there is a known threshold, and studies or data to establish that nothing happens below that level. Setting standards for these substances is relatively easy, because the information is available to determine safe levels to protect human health.

For carcinogens the situation is different. There is little human evidence to tell us the amount of a known or suspected carcinogen that will cause cancer. We also do not know much about the possible synergistic effects where more than one questionable substance may be present. In such cases, the total effect could be greater than the sum of the individual effects.

Toxicologists try to estimate the health effects of carcinogens, but 80 to 90 percent of the date they work from is animal data, extrapolated to humans, and only 10 to 20 percent is based on human experience. There are many uncertainties; species as different as rats and rabbits are from humans may not react the same way to a substance. Some substances found to cause cancer in mice do not cause cancer in rats, and these animals are much more alike than humans are to either.

Because there is so much uncertainty about cancer causes, "worst case" assumptions are made when EPA sets standards for known or suspected human carcinogens. They first assume that humans will react the same as test animals, and then assume that even one molecule of a carcinogen will react with DNA to cause cancer.



Toxicologists use a formula to estimate the "no observable effect level," and then add a safety factor of 100 times or 1,000 times that number, and set the limit that much lower. For carcinogens, the drinking water standards are thus set at a level believed low enough to cause no more than one cancer in one million people if ingested over a lifetime. Most experts agree that this approach tends to overestimate the cancer risk, but it does offer unquestionably strong public health protection.

To help people assess relative risks, the health risks are usually stated in terms of the expected number of health effects resulting from a given level of exposure. One way to evaluate a particular risk is to compare it with the probable number of health effects or deaths from other known causes. However, the same basic information can be presented in different ways. The way it is presented greatly influences our perception of risk.

Even the most scientific and unbiased risk assessment may still have little impact on our reactions to any risk connected with public drinking water.

Scientists can prove that we run far greater risks from smoking a cigarette or eating a food containing natural carcinogens than we are ever exposed to from public drinking water. They can point out that we consciously choose to take more dangerous health risks every day, in many of our activities.

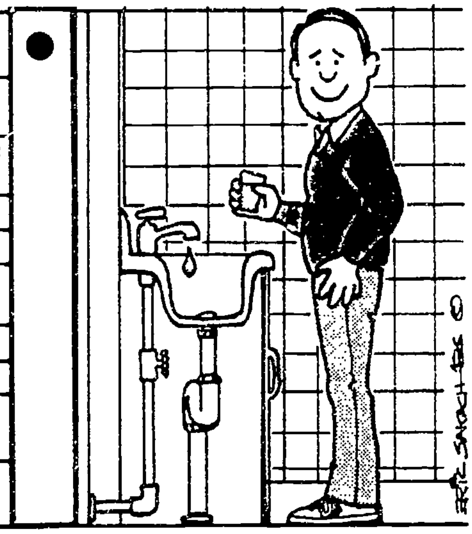
These arguments have little or no effect on the level of safety the public demands from drinking water. We are much more willing to accept a voluntary risk than any risk we perceive as imposed upon us. Risk assessment experts say we will spend 100 times as much to eliminate an involuntary risk as a voluntary one. Any risk connected with a public water supply is seen as an involuntary risk, and therefore unacceptable, no matter how low.

This attitude may change as more is known about the degree of health effects possible from toxic substances in given amounts in water, so that unfounded fears can be dispelled and actual health effects can be reliably estimated. Until then, consumers will probably continue to demand increasingly strict regulations for drinking water. It is only through extensive research and factual evidence that this trend will change.

WATER FACTS

HOW MUCH WATER DO WE USE?

- Taking a Bath or Shower
- Watering the Lawn and Yard
- Washing the Dishes by Machine/Hand
- Washing Clothes
- Washing the Car
- Brushing Your Teeth
- Cooking
- Drinking
- Flushing the Toilet (once)
- Leaking Toilet (per day)



ANSWER 9-12 GALLONS

HOW MUCH WATER DOES IT TAKE TO PRODUCE ONE SERVING OF:

- LETTUCE (1 cup)
- TOMATO CATSUP (1oz)
- WHITE SUGAR (1lb)
- WHOLE WHEAT BREAD (1 slice)
- TOMATOES (4.3oz)
- WHITE BREAD (1 slice)
- FRESH BROCCOLI (2.7oz)
- TOMATO PASTE (2oz)
- TOMATO SAUCE (4oz)
- ORANGES (4.6oz)
- BROWN RICE (1oz)
- WHITE RICE (1oz)
- PASTA (2oz)
- CANTALOUPE (8oz)
- BUTTER (0.36oz)
- MILK (8 fl oz)
- ORANGE JUICE (1 cup)
- CHEESE (1oz)
- TOFU (½ cup)
- EGG (1)
- ALMONDS (1oz)
- PLAIN YOGURT (1 cup)
- CHICKEN (8oz)
- HAMBURGER (4oz)
- STEAK (8oz)

ANSWER

GALLONS

PULL

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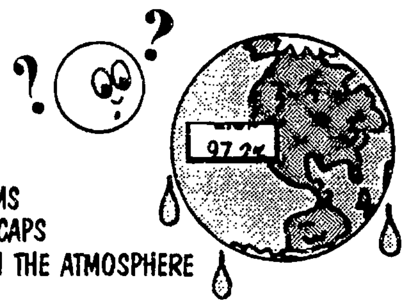
HOW MUCH OF THE EARTH'S WATER SUPPLY IS:



- SALT WATER
- FRESH WATER
- GROUND WATER
- LAKES & STREAMS
- GLACIERS & ICECAPS
- WATER VAPOR IN THE ATMOSPHERE

CALIFORNIA WATER SUPPLY QUIZ

HOW MUCH:

- Water runs off mountains in the form of rain or snowmelt?
- Water can California's reservoirs store?
- Ground water do we use?
- More ground water do we use than goes back into the ground?
- Water do we get from the Colorado River?
- Fresh water flows from the Delta into the ocean (on average)?
- Water does the federal Central Valley Project deliver?
- Water is delivered by the State Water Project?
- Water do state experts estimate we could be short by the year 2010?

answer

71 MILLION ACRE-FEET/YEAR

FACT:

One acre-foot equals approximately 325,900 gallons, enough to fill a football field to a depth of one foot or to supply the water needs of a household of up to five for a year.

FOR MORE FACTS, CONTACT:

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